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II SYMPOSIUM INTERNACIONAL  
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II INTERNATIONAL ANIMAL  
NUTRITION CONFERENCE

II JOURNÉES INTERNATIONALES  
DES ETUDES DE NUTRITION ANIMALE

II INTERNATIONALE STUDIENWOCHE  
FÜR TIERERNÄHRUNG

II SIMPOSIO INTERNAZIONALE  
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MADRID OCTUBRE 1960







*Spain.*

**INSTITUTO NACIONAL DE INVESTIGACIONES AGRONOMICAS**

<sup>20</sup>  
**II INTERNATIONAL ANIMAL  
NUTRITION CONFERENCE**



*500*  
**Madrid, 1960**



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THE UNIVERSITY OF CHICAGO

DEPARTMENT OF THE HISTORY OF ARTS  
AND ARCHITECTURE



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## INTRODUCTION

The Second International Animal Nutrition Conference was jointly organized by the Soybean Council of America, Inc. and the U. S. Feed Grain Council, Inc. as part of the world-wide program for market development of agricultural commodities that these two organizations have undertaken in cooperation with the Foreign Agricultural Service of the U. S. Department of Agriculture.

The top scientists in the field of animal nutrition got together in the Agricultural Research Institute of Madrid to exchange ideas and discuss the latest problems and accomplishments of this science.

The purpose of this Symposium was not simply to publicize U. S. agricultural products, but, on the contrary, to communicate and exchange points of view on the possibilities of the feed industry of the world in the belief that an animal agriculture will help all nations in their search for broad economic progress. As President of the Soybean Council of America, Inc. Mr. Howard L. Roach, has stressed, the abundance of American agriculture is not forcing the U. S. producers to dump the agricultural products on their neighbours but it has led these market development organizations—the Soybean Council of America, Inc. and the U. S. Feed Grain Council, Inc. — to undertake an important attempt to create the channels for distribution of these natural resources, without disrupting historical markets.

This Nutrition Conference brought together scientists from many nations, all experts of one or another of the most important economic activities in production and marketing of the animal products that our present world is increasingly demanding.

This Conference was held on an international basis because nutrition problems are no longer a domestic matter. The whole world has become aware of the fact that the production and distribution of food has to be planned on a world-wide scope.

The Organizing Committee thanks the effort of all participants and attendants.

## THE SOYBEAN COUNCIL OF AMERICA, INC.

The Soybean Council of America, Inc. came into being four years ago as an organization for market development of U. S. soybean agriculture and industry.

This is a non-profit organization whose main target is to promote consumption of soybeans and soybean products in order to create the channels for a world-wide distribution of this «miracle crop of the twentieth century».

The Home Office of the Soybean Council of America, Inc. is located at Waterloo, Iowa, and it counts on a large net-work with offices in Italy, Netherlands, Germany, Israel, Spain, India, Japan and recently Egypt.

The activities of the Soybean Council of America, Inc. are not only devoted to a program of market development, but also to an intensive program of cooperation and exchange of ideas among the different countries of the free world, in the belief that, mutual understanding will get all the free countries to know how to use and distribute their natural resources.

The Second International Animal Nutrition Conference is part of this program of exchange of ideas among technicians of countries having different types of problems, but all of them having a common basis: the need to feed an increasing population and to meet a growing demand for animal products.

«A modern agriculture» — said Mr. Roach, President of the Soybean Council of America, Inc. in a recent speech — «is an animal agriculture» and here, in the Symposium, are people of different countries believing in this basic idea.

## THE U. S. FEED GRAIN COUNCIL

The enormous development of livestock production in the United States has been largely due to the agricultural commodity supply available to the farmer.

It is well-known by all those who deal with Agriculture that the U. S. have managed to be the first world mass producer of many agricultural commodities. This has created a problem of agricultural abundance. The Feed Grain Council was created to open markets for many of these agricultural commodities to avoid their being stored and to make them available to millions of new consumers. The Feed Grain Council believes also in animal agriculture which may provide the growing population of the world with sufficient foodstuffs for a better living and a higher level of economic development.

Mr. Goeppinger is one of the founders of this organization and its first President; The Home Office of the Feed Grain Council is in Amarillo, Texas. A European Office has been recently opened in Rome under the direction of Mr. Charles Gidney.

## DISCUSSION MEETINGS AT THE 2nd INTERNATIONAL ANIMAL NUTRITION CONFERENCE

*Dr. Cuenca* (Spain). The technical sessions of the 2nd International Animal Nutrition Conference are hereby opened.

Before initiating the discussions for the First Panel, we will listen to Dr. Norris, from the United States, who by way of introduction will speak about *World Wide Problems in Animal Nutrition*. After this introduction, American and European Specialists will deal, species by species, with the different aspects and problems encountered in America and in Europe in the field of animal nutrition.

### X WORLD WIDE PROBLEMS IN ANIMAL PRODUCTION X

L. C. NORRIS

Cornell University, U. S. A.

In the consideration of «World Wide Problems in Animal Production», I have assumed that attention should be given both to the needs of the present world population for animal products but also as the population grows to future needs. At several recent scientific meetings it has been brought out that every year some 45,000,000 people are added to the world population and that according to the best estimations the population will double by the year 2,000. The great question facing us today is how to provide the present population of all areas with the bare essentials of an adequate diet and to make plans for the future to provide a more palatable, better-balanced diet, containing reasonable quantities of animal products to supply high quality protein and perhaps unknown nutritional values not easily furnished by means of foods of vegetable origin.



Only about one fifth of today's world population is obtaining an optimum intake of 2500-3000 calories per person per day. The other four fifths obtain a much smaller caloric intake, in some instances as little as one half that considered to be optimum. This level of caloric intake was found to be insufficient to maintain the weight and working efficiency of adults in England during the last world war or the weight of children.

To meet the needs of the increasing world population about 70 square miles of unused land should be put in cultivation of food crops every day. However, one fifth of the land surface of the earth is too cold to produce food, one fifth too arid, one fifth too mountainous and one tenth is bare. This leaves 30 per cent available for food production but only 10 % is now being used for this purpose.

The situation which I have just described appears offhand to be an exceedingly gloomy one but contrary to expectations the world food production is increasing at a slightly more rapid rate than the world population. The major difficulty, however, is that much of the increased production is in those areas where the population is relatively stable. As a consequence a form of malnutrition prevails in these areas which is caused by excess caloric intake rather than too few calories. In these areas the production of animal products is already well developed but undoubtedly can be increased with better fertilization of land, improved breeding, more adequate feeding, better disease control and greater mechanization and industrialization of agriculture.

The greatest number of large food producing domestic animals (cattle, sheep, and swine) is found in South America followed next in order by North America and Russia (USSR) then Western Europe and Africa and finally Asia with the lowest number. North America and Western Europe, however, have large numbers of poultry which supplement the food produced with large domestic animals. In India, surprisingly, the number of cattle per unit population is greater than that of any of the other areas previously mentioned.

It is obvious, however, when consideration is given to the nutritional status and caloric intake of the people of much of Africa and Asia and in many parts of South America, that the distribution of livestock in these countries is grossly uneven. Even if the distribution was more ideal, the consumption of animal products, due to greater cost of production, could not be greatly increased because of the low income level of the people. In central Africa, in Central America and also in some other low-income areas the quantity and quality of available protein is so low that kwashiorkor, a disease caused largely by protein deficiency, is endemic among the growing children.

In the thickly populated areas of Asia population increases with the food supply. Until effective measures can be developed for controlling population increase there can be little hope for developing a varied animal agriculture on a large scale basis. Perhaps even then all that can be accomplished in the distant future will be to increase the production of cereals and high protein oil seeds to the extent that the people are able to have a vegetable diet, adequate both in calories and protein. However, the example of India, where there is one cow or buffalo for every two people, indicates that the possibility exists in thickly populated areas for the development of an animal agriculture based on ruminants. The zebu cattle of India serve a fourfold purpose. They produce milk from which a clarified butter, called ghee, is made, are used to

provide meat to a limited extent, serve as draft animals and in many areas furnish the chief source of fuel.

The cattle are peculiarly adapted to a hot climate, are hardy and resistant to external pests and are perhaps the most efficient converters of low-grade roughage in the world today. Thus even in densely populated areas the inedible products incident to the production of food for man apparently will serve to maintain many ruminants provided they are suitably adapted to such roughage, particularly in areas in which some of the land is only useful for the production of low-grade pasture.

Because of the long-term nature of the difficulties that I have just discussed, I believe that we must differentiate at this Symposium between the livestock problems in the low-income, deficiency areas of the world, since little can be done about them at present, and apply ourselves chiefly to the livestock problems in the high-income areas where animal agriculture is already well developed. We should realize, of course, that the research findings which we consider and the results of any research programs that we stimulate here will be generally available and can be made use of as animal agriculture develops in the years ahead in those countries of the world where now income and food production are too low to sustain this type of agriculture.

The problems in livestock production in Western Europe, most of North America and the southern part of South America are familiar in a general way, I am sure, to most of us attending this Symposium. As indicated by the program these problems are chiefly in the fields of nutrition, genetics and animal breeding, disease control, and processing and quality of animal feeds. It is my plan in presenting this paper to discuss these four areas briefly and in such a way as not to infringe upon the presentations of the speakers who follow me on this program.

In animal nutrition the discovery of new dietary essentials has been thought by some investigators to be nearing an end. Yet only yesterday selenium, a mineral element, formerly studied only because of toxic problems arising from grazing animals on pasture plants or fed grains grown on seleniferous soil, was found to be an essential mineral element for rats, chicks and sheep. Whitemuscle disease of sheep, observed in some parts of the United States, Australia and New Zealand has been found to be primarily a selenium deficiency, although in most instances preventable with vitamin E. Evidence has also been presented that the dietary agent required for the maintenance of glucose tolerance in the rat is chromium. Furthermore, chromium as well as vanadium and nickel appear to be components of biologically active native compounds. Thus it seems that through the development of more highly refined technics and more highly purified diets, other trace minerals may be added to those already found to be essential.

Research workers are also continuing to obtain evidence of the existence in crude feedstuffs of the presence of unidentified substances which at times stimulate the growth of pigs and poultry. Whether or not these substances are in the nature of vitamins is not known. They are found largely in meat and fish products, milk products, yeast products and grass and alfalfa extracts.

The chief difficulties in the way of isolating and identifying the substances are (1) the inability as yet to develop experimental diets free of these substances, (2) the possibility that they are needed only for early growth and that storage in the body tissues at birth frequently enables young pigs and chicks to meet



their needs during this critical period of life and (3) the great possibility that some synthesis of these substances occurs either in the tissues or by bacterial action in the gut but not always in amounts sufficient for maximum growth.

The present status of this phase of animal nutrition requires that research on the unidentified growth-promoting substances in certain crude feedstuffs be continued until they are identified, methods for analyzing feedstuffs for them developed and the quantities present determined.

The interrelationship of nutrients and of nutrients with inhibitory substances, is a phase of nutrition in which a great deal of research has been conducted. All animal nutritionists are of course familiar with the interrelation which has been known to exist for many years between energy and protein. Recent research, however, has emphasized the possibility that some control of body fat deposition can be made by appropriate adjustments in the energy-protein ratio of animal rations. This is a matter of great practical implications not only because the production of animal fat is costly compared to vegetable fat but also because its consumption in excess leads to overweight and other evidences of malnutrition.

Some of the most interesting interrelationships which have been revealed are those which exist between the trace minerals or affect the requirements for them. One of the more important from a practical point-of-view is the one between copper and molybdenum and sulfate ion. Others of great importance in metabolism are the associative relationships between calcium, phosphorus and vitamin D in bone formation and that between iron and copper in the formation of hemoglobin. Still others are selenium and vitamin E, selenium and arsenic, molybdenum and tungsten. An interrelationship discovered long ago is the sparing effect of fat on the thiamine requirement. A recent one which needs confirmation is the report that high levels of fat greatly increase the requirement for vitamin B<sub>12</sub>. These examples of nutrient interrelationship are referred to here only to bring out the importance of these effects and the need to continue to study them because of their influence on the quantitative requirements for nutrients.

Research findings in animal nutrition are not of the greatest value unless the research is carried out to the point where they can be applied practically. For the most part this demands that the quantity of each nutrient required per unit of feed for each type of food animal, or the quantity required per unit weight per day be determined. It is also necessary that analytical procedures for determining the amount of each nutrient in the common feedstuffs be developed and the amount present in these feedstuffs be ascertained.

The Committee on Animal Nutrition of the United States National Academy of Sciences-National Research Council and its subcommittees on the nutrition of the various types of domestic animals has been engaged for nearly twenty years in the development of feeding standards, giving quantitative nutrient requirements for growth, production and reproduction. Most of the reports containing these feeding standards have been revised several times as new evidence on quantitative requirements became available. Simultaneously with the preparation of these feeding standards, the NAS-NRC Committee on Feed Composition compiled into reports all the available data of a reliable character in United States laboratories on the composition of feed ingredients. The feeding standards and the data on feed composition have proven of inestimable value to animal nutritionists and feed manufacturers in the United States and

Canada in the formulation of adequate rations for domestic animals. Unfortunately because of lack of available evidence the tables of nutrient requirements and the tables of feed composition are by no means complete. Therefore, the encouragement of further research on the quantitative nutrient requirements of domestic animals and more complete analyses of the common feedstuffs for essential nutrients is highly desirable.

In animal breeding one of the great problems is the breeding of food animals which are better adapted to environmental and other conditions and which are of the greatest economic productivity. At the same time the further development of suitable types of food animals requires that much more consideration be given to consumer preference than has been done in the past. One of the striking examples of recent years of improved adaptation to environment has been the development of the Santa Gertrudis breed of beef cattle and similar strains in the United States. By crossing Brahman and Shorthorn cattle, a breed more resistant to external pests and better adapted to a hot climate has been obtained which at the same time produces beef of acceptable quality.

A somewhat similar development has taken place in the United States in the meat types of poultry. By means of up-to-date selection procedures and the use of strain crosses it has been possible to increase rate of growth and quantity of edible carcass in chicken and turkeys. A reduction in age of marketing with resultant improvement in feed efficiency has accompanied these developments in poultry breeding. Resort to the use of high-energy rations aided materially in attaining this end.

In recent years the need to develop types of beef cattle and swine which produce meat of acceptable quality without accompanying high fat content has come to the forefront in the United States. Housewives in general are attempting to keep the caloric intake of adult members of the family at levels which prevent excessive overweight and they have come also to look with askance upon the consumption of large amounts of saturated animal fat because of reported undesirable effects upon the blood circulatory system. In Canada and in Denmark where breeds of swine less inclined to lay down fat are raised, leaner pork is being produced but in the former country this is accompanied by the feeding of less efficient, more fibrous and bulky rations which slows up the rate of growth. Such rations are unsuitable to United States conditions where highly digestible corn is the preponderant feed grain. Not too much progress has been made in the United States, therefore, in the use of breeds of swine which produce lean pork because of the difficulty of doing this on high corn rations. The same situation appears to hold in the case of beef cattle, since the most palatable beef is obtained by overfattening in the feed lot on high-carbohydrate grain.

In the field of animal disease many of the livestock problems lie in the control of disease rather than treatment. Most of the more serious ailments of domestic animals in the United States and Canada can be taken care of by vaccination, good nutrition and good management, but some diseases still remain to be conquered, notably leucosis in chickens, and the mortality among young animals is altogether too great. Dangerous foreign animal diseases, however, are kept out by the enforcement of strict inspection and quarantine regulations and prohibition of importation of animals from countries in which such diseases are enzootic. In spite of these measures exotic animal diseases



sometimes break out, requiring the use of local quarantines and destruction of infected animals. Such measures are costly and disruptive of the orderly movement of livestock. They are indicative of the necessity of studying the exotic diseases and developing more adequate control measures than those at present available. The NAS-NRC Committee on Animal Disease, because of the present status of the knowledge of animal disease, has recently published a brochure calling attention to the need of much larger appropriations in the United States for the training of research workers in this field and the support of a greatly enlarged research program.

In the further study of animal disease the veterinarian will frequently need the cooperation of other scientists. An example of this is the recently developed procedure for the control of the screw worm in cattle by entomologists in the United States Department of Agriculture. This has led to the elimination of the screw worm fly in the Florida area of the United States. The elimination was accomplished by the large-scale release of gamma-ray sterilized males among the natural population. Since the screw-worm female mates only once, this procedure eventually leads to the elimination of the entire screw worm population. The successful use of gamma-ray sterilization of male screw worm may eventually lead to the application of similar procedures in controlling other livestock pests.

In the control of quality of animal feedstuffs, climate, soil composition, and degree of fertility, are conditions which affect the quality of pasture for ruminants and the additional factors of processing and storage affect the harvested roughages and grains. Some feedstuffs such as soybeans and cottonseed possess characteristics which are detrimental to some classes of livestock until subjected to processes which overcome them. These have been studied extensively and the production of superior quality soybean oil meal is almost universal in the United States. Knowledge of the effect of processing on quality of protein has greatly increased over the years and animal and fish products for feeding swine and poultry possessing protein of as good quality as it is possible to make, depending upon the original material, can be readily manufactured. Inexpensive, synthetic nutrients have been made available by industry with the result that it is easier to formulate optimum rations for domestic animals than formerly. As pointed out previously, however, many gaps exist in the knowledge of the composition of feedstuffs. Moreover since animals are frequently fed materials which are by-products in the production of food for man, and thus highly variable in respect to many of the usual criteria of quality, the control of quality in feedstuffs presents many difficulties which will not be of easy solution.

From the evidence which I have presented it seems clear that we have learned much about the problems of animal production and have arrived at the solution of some of them. I can see no reason for complacency, however, since in my opinion the solution of those problems of which we are now aware and of those which are still unknown will require greater effort and the expenditure of much larger sums of money than put into this work in the past. All this is necessary in order to maintain the adequacy of the diet of the people of the well-developed areas of the world and improve the diet of the people in the under-privileged areas as world population increases. I am confident that many research workers will approach these problems eagerly and derive great satisfaction in working them out.

*Dr. Cuenca* (Spain). Now that we have listened to the wonderful presentation made by Mr. Norris regarding world wide problems in animal nutrition, for which we can't but congratulate him very sincerely, I leave the Chairmanship of the Panel to Dr. Simonnet who will direct the Sessions taking place under Panel I.

## PANEL I

*Dr. Simonnet* (France). First of all I would like to express my gratitude to the Secretary General for honouring me with the Chairmanship of this interesting panel.

Now, Mr. L. E. Hanson will talk about the following subject: *Swine: Recent Trends and Developments in the United States*, after which Dr. de Juana Sardón will develop the same subject referred to European swine husbandry, with special emphasis on the Spanish situation. After these two reports, there will be a discussion session.

### SWINE: RECENT TRENDS AND DEVELOPMENTS IN THE UNITED STATES

L. E. HANSON

University of Minnesota, St. Paul, Minnesota  
U. S. A.

Swine production in the major producing areas of the United States is going through a period of relatively rapid change. Most issues of the popular farm magazines contain stories on confinement rearing of swine, mechanization of feeding operations, manure disposal, building plans and other subjects that reflect the changes which are taking place. There is more apparent interest in and more questions are being asked about management, equipment and building plans than about nutrition by the leading swine producers of the Nation. This is probably a reflection of the fact that we lack data from well controlled research in many aspects of management, including housing.

#### *Increased emphasis on carcass quality*

There is a greater awareness today among swine breeders and producers than there has been at any time in the past, of the importance of carcass quality. Historically, swine production developed in the United States as a method of marketing corn and little attention was paid by producers to carcass quality except that the pig should be fat.

The American consumers today are selective in their choice of meats and they have made it clear that they do not want fat meat, especially pork.



Furthermore, the tremendous growth and development of the poultry meat industry, particularly broilers and turkeys, during the past 15 years has resulted in significant competition for the consumer's food dollar. In this competition the swine producer has lost part of his former market.

Traditionally, swine breeding in the United States has been an art and progress by most breeders was judged primarily on the basis of results in the show ring. During the past five years swine testing stations have been established at a rapid rate so that today 24 of the states have one or more testing stations. Many participating breeders during these few years have been surprised to find that their pigs were deficient in growth rate, feed efficiency or carcass quality, as judged by our present standards.

The impact of these testing programs has already been felt by the breeders and is having a significant effect on producers as well. Today the alert producers are crowding the breeders to supply better and better performance records. In a recent major swine sale a boar pig that placed sixth in his class brought \$200 more at auction than the champion of the breed because the former had littermates that had been tested and the records showed that they had outstanding carcass quality. The champion came from tested stock too, but the records were not as good.

### *Pasture is less important*

For the first half of this century, Experiment Station and Extension personnel in the United States stressed the importance of pasture. This was good advice because pasture was of great value in correcting the nutrient deficiencies of many of the swine rations commonly fed. Research during those years generally showed that the use of good pasture increased live weight gains and reduced the feed required per unit of gain. In addition, pasture-fed pigs usually were more thrifty.

Since 1955 research workers have deemphasized the importance of pasture for growing pigs because many have experienced the kind of results summarized by Conrad of the Indiana Station (1) as shown in Table 1. These data were obtained from studies conducted at six experiment stations.

TABLE I  
PASTURE VERSUS DRY LOT FOR GROWING PIGS (RECENT RESULTS)

| Where fed                  | On concrete | On pasture |
|----------------------------|-------------|------------|
| No. of pigs                | 474         | 474        |
| Av. daily gain, lb.        | 1.56        | 1.58       |
| Feed per 100 lb. gain, lb. | 320         | 310        |
| Feed cost per 100 lb. gain | 9.29        | 8.96       |

These data show that pigs full-fed modern rations gain as rapidly when fed in dry lot as when fed on pasture. The use of pasture does result in a slight reduction in feed required and feed cost per unit of gain, but the saving

is so small that most farmers can obtain larger returns by using the land for crop production. It is recognized, of course, that the farmer who has poor dry lot facilities (no concrete or other hard surfaced feeding areas) will produce pigs more economically by use of good pasture. A recent study by Wisconsin and U. S. Department of Agriculture workers (2) showed that good pasture has a much higher value when the feed allowance is restricted, than when animals are full-fed.

*Value of exercise for swine has been overemphasized*

Exercise for swine has been stressed by U. S. swine specialists for many years as conducive to health and well-being, particularly for breeding stock. However, results of studies by the writer (3), started 15 years ago, cast doubt on the importance of exercise for growing boars. A recent three year study reported by the Ohio Station (4), has shown that breeding females can be raised in confinement on concrete for several generations with success. Conrad (1) has summarized the results of four experiments conducted at the Indiana Station with growing pigs (Table 2), in which once group of pigs was driven one mile daily and one group was confined.

TABLE II  
EXERCISE FOR GROWING PIGS

| Treatment                  | Daily<br>exercise | Confined |
|----------------------------|-------------------|----------|
| No. of pigs                | 60                | 60       |
| Initial weight, lb.        | 58                | 58       |
| Final weight, lb.          | 225               | 225      |
| Av. daily gain, lb.        | 1.66              | 1.79     |
| Feed per 100 lb. gain, lb. | 386               | 375      |

These data show that exercise reduced the rate of gain and increased the feed required per unit of gain. As would be expected, exercised pigs were not as fat as the confined pigs. However, daily exercise is not recommended as a method of improving carcass quality.

*Reference rations have changed*

Fifty to 60 years ago, corn and skim milk was the ration with which other rations for pigs were compared in the U. S. A. Later corn and tankage became the reference standard. Following the discovery of vitamin A, the late F. B. Morrison and associates of the Wisconsin Station developed a mixed supplement (tankage, linseed oil meal and alfalfa meal) for feeding with corn which became well and favorably known as the «trio mixture». This was the first attempt in the U. S. A. to combine feeds which would not only supplement the deficiencies of corn protein, but also provide additional vitamins, par-



ticularly A and D. Other supplemental mixtures were developed and for a period that lasted nearly 30 years, up to 1950-55, the desirability of including a mixture of proteins of animal and vegetable origin in a supplement for swine was stressed by most research workers. This was done to insure good quality of protein in the ration though hindsight tells us that vitamins other than A and D were involved as well. The mixed supplement and corn thus became the referente standard for testing of new or old ingredients.

Soybean oil meal was introduced into these mixtures in the 1930's as supplies became more readily available and by 1940 it had been tried as the only source of supplementary protein in corn rations. At this time, corn, soybean oil meal, minerals and certain vitamins did not constitute a satisfactory ration for pigs in dry lot. The isolation of vitamin B<sub>12</sub> in 1948 provided the missing link which led to the present successful use of large quantities of soybean oil meal in U. S. swine rations.

#### *Commercial developments permit new approach in ration formulation*

Vitamin D has been available for many years at low cost in the form of irradiated yeast. Soon after its isolation vitamin B<sub>12</sub> was made available as a feed supplement. The past 10-12 years have also witnessed the development of low cost feed supplements containing guaranteed potencies of riboflavin, nicotinic acid and pantothenic acid and the development of synthetic, stabilized vitamin A in a dry, free-flowing form. These supplements have enabled research workers to reevaluate the high protein feeds as sources of amino acids.

#### *Soybean oil meal as a source of supplementary protein*

The amino acid requirements of growing pigs, under 75 lbs. in weight, have been studied extensively in the U. S. A. during the past 12 years. This subject has been discussed by others on this program and will not be discussed here. Recent summaries have been prepared by the Sub-Committee on Swine Nutrition, National Research Council (5) and Becker (6).

Many studies have been made during recent years of the value of soybean oil meal as a supplementary protein for pigs fed corn, barley or grain sorghums. Some of the more recent studies with growing pigs are summarized in Table 3. In all of these studies the rations were fortified with riboflavin, nicotinic acid, pantothenic acid, vitamin B<sub>12</sub> and when alfalfa meal was not used, with vitamin A. An antibiotic was fed also. With one exception (noted) the pigs were fed to approximately slaughter weights. These data for corn and barley rations are presented because they are recent and because few such data appear promptly in the journals. The Oklahoma data have been published (7) (8).

In a study conducted this past winter at Minnesota by Meade *et al* (9), detailed carcass data were obtained from half of the pigs fed (Table 4). In this study, three protein sequences, 19-15 %; 16-13 %; and 14-11 % were fed with each source of protein. The higher levels, 18, 16 and 14 % were fed until the pigs weighed 100 lbs. and the lower levels thereafter. The two higher protein sequences produced the leaner carcasses, irrespective of protein source.

TABLE III

SOYBEAN OIL MEAL AS A SOURCE OF SUPPLEMENTARY PROTEIN FOR PIGS

| Protein source (1)                           | No. pigs<br>fed | Initial<br>wt., lb. | Av. daily<br>gain, lb. | Feed / lb.<br>gain, lb. | Source of data     |
|----------------------------------------------|-----------------|---------------------|------------------------|-------------------------|--------------------|
| <i>Corn Rations</i>                          |                 |                     |                        |                         |                    |
| Soybean oil meal                             | 26              | 52                  | 1.69                   | 3.55                    | Minn., 1957 (9)    |
| SOM + linseed oil meal                       | 26              | 53                  | 1.56                   | 3.57                    |                    |
| SOM + tankage                                | 26              | 53                  | 1.72                   | 3.46                    |                    |
| SOM + LOM + T                                | 26              | 52                  | 1.58                   | 3.62                    |                    |
| Soybean oil meal                             | 15              | 52                  | 1.72                   | 3.34                    | Minn., 1958 (9)    |
| SOM + tankage                                | 15              | 52                  | 1.59                   | 3.46                    |                    |
| SOM + dried whey                             | 15              | 51                  | 1.76                   | 3.27                    |                    |
| SOM + fish meal                              | 15              | 54                  | 1.75                   | 3.34                    |                    |
| Soybean oil meal                             | 16              | 63                  | 1.70                   | 3.75                    | Minn., 1959 (9)    |
| SOM + tankage                                | 16              | 63                  | 1.82                   | 3.65                    |                    |
| SOM + T + linseed oil meal                   | 16              | 63                  | 1.74                   | 3.51                    |                    |
| SOM + T + LOM + fish meal +<br>alfalfa meal  | 16              | 63                  | 1.73                   | 3.54                    |                    |
| Soybean oil meal                             | 10              | 41                  | 1.67                   | 3.10                    | Mich., 1960 (11)   |
| SOM + meat and bone scraps<br>+ alfalfa meal | 10              | 41                  | 1.59                   | 3.16                    |                    |
| Commercial mixture                           | 10              | 41                  | 1.47                   | 3.41                    |                    |
| Soybean oil meal                             | 8               | 83                  | 1.78                   | 3.63                    | Florida, 1959 (10) |
| Tankage                                      | 8               | 83                  | 1.63                   | 3.68                    |                    |
| SOM + T                                      | 8               | 84                  | 1.68                   | 3.70                    |                    |
| Soybean oil meal                             | 10              | 34                  | 1.27                   | 2.84                    | Florida, 1959 (10) |
| Tankage                                      | 10              | 33                  | 0.90                   | 3.31                    |                    |
| SOM + T                                      | 10              | 34                  | 1.28                   | 3.05                    | (fed for 56 days)  |
| Soybean oil meal                             | 10              | 97                  | 1.77                   | 3.68                    | Florida, 1959 (10) |
| Commercial mixture                           | 10              | 97                  | 1.67                   | 3.61                    |                    |
| <i>Barley Rations (pelleted)</i>             |                 |                     |                        |                         |                    |
| Soybean oil meal                             | 29              | 41                  | 1.58                   | 3.66                    | Minn., 1959 (9)    |
| SOM + fish meal                              | 29              | 41                  | 1.70                   | 3.64                    |                    |
| Corn + SOM control                           | 27              | 41                  | 1.58                   | 3.58                    |                    |
| Soybean oil meal                             | 20              | 48                  | 1.66                   | 3.50                    | Minn., 1960 (9)    |
| SOM + blood meal                             | 20              | 49                  | 1.59                   | 3.74                    |                    |
| SOM + tankage                                | 20              | 49                  | 1.57                   | 3.66                    |                    |
| SOM + fish meal                              | 20              | 51                  | 1.69                   | 3.76                    |                    |

1) SOM = soybean oil meal; LOM = linseed oil meal; T = tankage; COM = cottonseed oil meal; FM = fish meal; B = buttermilk.

TABLE III (Cont.)

| Protein source                       | No. pigs fed | Initial wt., lb. | Av. daily gain, lb. | Feed / lb. gain, lb. | Source of data  |
|--------------------------------------|--------------|------------------|---------------------|----------------------|-----------------|
| <i>Grain Sorghum Rations</i>         |              |                  |                     |                      |                 |
| Soybean oil meal                     | 32           | 49               | 1.63                | 3.54                 | Okla., 1955 (7) |
| Tankage                              | 32           | 49               | 1.53                | 3.60                 |                 |
| SOM + T                              | 32           | 48               | 1.57                | 3.68                 |                 |
| SOM + fish solubles                  | 32           | 49               | 1.67                | 3.66                 |                 |
| SOM + blood meal                     | 32           | 52               | 1.57                | 3.69                 |                 |
| Soybean oil meal                     | 16           | 48               | 1.44                | 3.79                 | Okla., 1956 (8) |
| 3/4 SOM + 1/4 cottonseed oil meal    | 16           | 48               | 1.45                | 3.80                 |                 |
| 1/2 SOM + 1/2 COM                    | 16           | 48               | 1.27                | 4.15                 |                 |
| Soybean oil meal                     | 16           | 64               | 1.56                | 4.11                 |                 |
| SOM + fish meal                      | 16           | 64               | 1.53                | 4.20                 |                 |
| SOM + buttermilk                     | 16           | 64               | 1.52                | 4.16                 | Okla., 1956 (8) |
| SOM + FM + B                         | 15           | 64               | 1.44                | 4.47                 |                 |
| Soybean oil meal                     | 8            | 62               | 1.73                | 3.49                 |                 |
| SOM + 2 % sesame meal                | 8            | 64               | 1.65                | 3.50                 |                 |
| SOM + 4 % sesame meal                | 8            | 65               | 1.57                | 3.65                 |                 |
| SOM + 4 % sesame meal + 0.1 % lysine | 7            | 70               | 1.68                | 3.70                 |                 |

TABLE IV

THE EFFECT OF PROTEIN SOURCE ON GROWTH AND ON SOME CARCASS CHARACTERISTICS

| Protein source                | Soybean oil meal | SOM / meat and bone scraps | SOM / fish meal |
|-------------------------------|------------------|----------------------------|-----------------|
| No. of pigs fed               | 48               | 48                         | 48              |
| Av. daily gain, lb.           | 1.68             | 1.72                       | 1.62            |
| Feed/lb. gain, lb.            | 3.55             | 3.49                       | 3.52            |
| Carcasses (1)                 | 24               | 24                         | 24              |
| Slaughter weight, lb.         | 199              | 200                        | 202             |
| Length, inches                | 30.3             | 30.7                       | 30.5            |
| Carcass weight/live weight, % | 70.4             | 70.1                       | 70.1            |
| Backfat thickness, inches     | 1.45             | 1.51                       | 1.55            |
| Lean cuts/live weight, %      | 35.1             | 34.6                       | 35.2            |
| Loin eye area, sq. inches     | 3.10             | 3.02                       | 3.24            |

- 1 All carcasses were from barrows; backfat thickness is an average of 3 measurements; lean cuts include trimmed ham, loin and shoulder; loin eye area is based on the cross section of the longissimus dorsi between the 10th and 11th rib-measured from tracings, with a planimeter.

The data presented in Tables 3 and 4 illustrate well the fact that soybean oil meal is an excellent source of amino acids and is a satisfactory protein supplement for corn, barley or grain sorghum rations.



A recent study reported by the Virginia Station (12), of which a part is summarized in Table 5, shows that soybean oil meal is clearly superior to peanut oil meal and fully equal to a mixture of peanut oil meal and blood meal or fish meal as a source of amino acids for supplementing a corn ration. This study indicates too that lysine is of special importance insofar as muscle development of the pig is concerned. The addition of lysine to the peanut meal ration increased the loin eye area significantly, as did blood meal and fish meal both of which are usually good sources of lysine.

TABLE V

THE EFFECT OF PROTEIN SOURCE ON GROWTH AND ON SOME CARCASS CHARACTERISTICS

| Protein source (1)        | SOM  | POM  | POM/lysine | POM/lysine<br>methionine | POM/blood<br>meal | POM/<br>fish mea <sup>1</sup> |
|---------------------------|------|------|------------|--------------------------|-------------------|-------------------------------|
| No. of pigs fed           | 6    | 6    | 6          | 6                        | 6                 | 6                             |
| Initial weight, lb.       | 52   | 55   | 50         | 51                       | 53                | 54                            |
| Av. daily gain, (2) lb.   | 1.53 | 1.19 | 1.31       | 1.48                     | 1.53              | 1.51                          |
| Feed/lb. gain, lb.        | 3.54 | 5.28 | 4.01       | 3.57                     | 3.65              | 3.75                          |
| Final weight, lb.         | 208  | 193  | 199        | 203                      | 202               | 209                           |
| Av. carcass. length, in   | 30.0 | 30.1 | 29.3       | 29.8                     | 29.7              | 30.1                          |
| Av. backfat, inches       | 1.4  | 1.4  | 1.4        | 1.5                      | 1.4               | 1.4                           |
| Loin eye area (2) sq. in. | 3.72 | 3.17 | 4.25       | 3.60                     | 3.91              | 3.58                          |

1) SOM = soybean oil meal; POM = peanut oil meal.

2) Adjusted means. Carcass measurements were obtained by the same procedure given in footnotes of Table 4.

Teague and Rutledge (4) fed gilts in confinement rations adequate in energy, minerals and vitamins and supplemented with soybean oil meal or with meat and bone scraps and soybean oil meal. Groups were fed continuously one of these two rations through the farrow of 4th generation pigs. Satisfactory performance was maintained on both ration treatments and there was no decline in performance either from the ration treatment or as a result of continual confinement on concrete. Significantly greater birth weights and greater average vigor at birth of pigs farrowed by second and third generation females was observed in the group fed meat and bone scraps, in addition to soybean oil meal.

### Minerals

The increased use of soybean oil meal has resulted apparently in renewed interest in mineral nutrition of swine. The recent experience with parakeratosis led to recognition of zinc as an essential element for growing pigs (13) and resulted in more caution in the fortification of rations with calcium and the general use of supplementary zinc at level of 40 to 100 ppm. Rutledge (14) has demonstrated that pigs 3 to 8 weeks of age require at least 0.8 % Ca. in the ration for normal bone development. Teter (15) estimated the phosphorus requirement of pigs weighing 12 to 50 lbs. to be 0.50 % of a diet containing 0.8 % Ca. The minimum phosphorus requirement for growth (from 50 lbs. to



breeding age) reproduction and lactation was estimated to be 0.35 % of the ration. The ration contained 0.8 % Ca.

The value of injectable iron for anemia prevention in suckling pigs has been extensively studied during the past 3 years. At last count there were at least 20 different preparations offered on the market. The iron dextran product (16) originally developed by Bengel Laboratories (England), and iron dextrin products have generally produced excellent results. Several ferric ammonium citrate products tested by experiment stations have been quite toxic to young pigs. Several other commercial products are relatively ineffective because they do not supply enough iron. The present evidence indicates that 150 mg. of injectable iron as the dextran or dextrin complex is the optimum dose if pigs are not weaned before 5 weeks of age. Injectable iron has been well accepted by producers.

There has been increased interest recently in the use of copper sulfate in swine rations. One station (17) presently is recommending the addition of 2 lb.  $\text{Cu SO}_4 \cdot 5\text{H}_2\text{O}$  per ton of feed for growing pigs.

### *Antibiotics*

Studies of antibiotics and other antibacterial agents continue, though at a reduced pace when compared with past years. Recent studies have been concerned with various combinations such as penicillin-streptomycin, bacitracin-penicillin, streptomycin-sulfaquinoxaline, various antibiotics and arsanilic acid and others. Among the recently tested individual compounds which appear to have promise are: erythromycin, spiramycin, neomycin, oleandomycin, tylosin, and furazolidone. The older broad spectrum antibiotics, chlortetracycline and oxytetracycline are still effective and generally used, though they frequently appear in combination with other antibiotics. A recent report by Teague (18) on the use of chlortetracycline, over a period of 9 years, does not indicate that this antibiotic has lost its effectiveness in swine rations. In view of the suspected mode of action of antibiotics, variable results should be expected under differing environmental situations. The results obtained by different experiment stations do vary and they vary also at different times at the same station.

### *Summary*

Swine production practices are changing at a relatively rapid rate in the United States. Developments in nutrition knowledge have made possible large scale swine production in confinement. There is a definite trend toward confinement rearing of swine.

The phenomenal increase in soybean production and the high quality of average soybean oil meal has made possible the use of this product as the only or major source of supplementary amino acids in corn, barley and grain sorghum rations.

Today high protein feeds are considered primarily on the basis of the amino acids they contain because industry has provided vitamin supplements at relatively low cost.

The development of testing stations has focused attention on production

costs and carcass quality of swine. Today the American breeder and commercial producer is more aware of the importance of carcass quality than at any previous time in history. Significant progress has been made by breeders and producers in the production of swine which yield leaner carcasses.

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#### ANTIBIOTICS IN ANIMAL NUTRITION,

Swine: Recent Trends in the European Area

BY

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Only a decade has elapsed since the stimulating effect of antibiotics on animal growth became a known fact as a practical proposition. Although Moore and co-workers pointed out as early as 1946 the stimulating action of streptomycin, it may be considered that the starting point of the application of antibiotics in this field was determined by the results reported by STOCKAD and co-workers, using residues of aureomycin fermentation (1949).

From this date onwards, several research activities were undertaken, most of them confirming and supporting the initial findings. The first scientific



work demonstrating the value of antibiotics in pig feeding was published in April 1950. In October 1950, antibiotics were officially defined and approval for their use in animal feeding was given by the American Feed Control Officials.

Subsequently, the practical application of antibiotics to animal nutrition was initiated, especially in the United States. In Europe, this application took place somewhat later and it was approached differently, both from the technician-producer as from the legislator point of view.

The practical application of antibiotics to animal nutrition was initiated on a limited scale in 1952. In most countries antibiotics were not officially sanctioned until some time later, the beginning of 1954. The official position regarding this new development varies considerably in different countries although, generally all countries require a special authorization for adding antibiotics to mixed feeds, under the general heading of «special active ingredients». Let us review this situation in more detail.

Austrian legislation establishes the methods to be used for the analysis of penicillin, aureomycin and terramycin in animal foodstuffs. A special license is required to use antibiotics in animal nutrition, which is issued by the Austrian Ministry of Agriculture.

In Belgium also, a special license is required for the incorporation of «growth stimulants» in animal feeds.

Finland does not enforce any special permit, however the amounts of antibiotics added to the feed must be duly reported. The antibiotics content, or the proportion of any other therapeutic agents must be indicated in units of weight per kilogram of the product, a 30 % proportion being permitted.

In France, where they have had antibiotic legislation since 1954, the addition of aureomycin, penicillin, bacitracin and terramycin is permitted.

In Holland, a special license is required. For the incorporation of antibiotics in artificial milks for piglets the following conditions must be met: a) cellulose content should not exceed 1 % of dry substance, while protein content should not be under 25 %; b) the maximum proportion or dose of antibiotic should not exceed 5 grams per 100 kilograms of dry substance; c) the product must be labelled «piglet milk with antibiotic content».

Norway, according to a legislation introduced in 1956, requires a special license for incorporating antibiotics in calf, swine and poultry rations. The admitted antibiotics are penicillin, terramycin and aureomycin at the rate of 15 mg. per kilogram of feed. For calf feeds and pig concentrates doses up to 50 mg. per kilogram are admitted.

In Sweden no license is required for antibiotic incorporation in animal feeds; however, the amounts incorporated must be reported.

Switzerland requires a special authorization, which is now granted for penicillin, aureomycin and terramycin at the rate of 5 to 20 grams per metric ton, with an indication as to the nature of the product added, activity and instructions for its use.

Great Britain has regulated the use of penicillin, aureomycin and terramycin for mixing with certain foodstuffs for swine and poultry.

Portugal has recently established a legislation regarding this important development.

In Spain, the use of antibiotics in animal nutrition on an industrial level



was initiated in 1955, and was regulated in 1957, permitting the incorporation of aureomycin, bacitracin, penicillin and terramycin in animal rations; terramycin was approved at later date. Spanish legislation establishes the following provisions:

C) *Antibiotics:*

The role played by antibiotics as growth stimulants being a well-known fact, its use in the elaboration of both mixed feeds and correctors will be allowed.

The main antibiotics approved, with their corresponding proportions, are the following:

*Aureomycin:* 10 to 50 grams per ton.

*Bacitracin:* 5 to 10 grams per ton.

*Penicillin:* 4 to 10 grams per ton.

*Terramycin:* 7 to 50 grams per ton.

These products will be added to balanced rations, and must be uniformly mixed to the feed.

The manufacturers of mixed feeds are obliged to state on the labels of their packages the type of antibiotic added to the product and, for correctors, exact instructions and directions for use must be specified.

Taking into account the evolutionary stage of our present knowledge about the effect of antibiotics on nutritive processes, additional regulations will be established on the basis of any new conclusions and developments attained.

The use of high levels of antibiotics for preventive purposes shall be subjected to special authorization from the Dirección General de Ganadería, Ministry of Agriculture.

The doses recommended as growth stimulants are influenced by cost factors, which represent about 0.15 pesetas per kilogram of feed, considering the prices of supplements in the Spanish market.

In May 1955 the First Symposium on Antibiotics and Growth Factors of Animal Nutrition was held in Rome; in October of the same year a First International Conference on the Use of Antibiotics in Animal Feeding took place.

It will be noted, therefore, that the use of antibiotics to a certain scale only started about eight years ago, which is a rather short period of time for establishing any definite conclusions.

From the experience acquired so far, the following practical conclusions may be established regarding *antibiotic applicability*:

a) Antibiotics determine an increase in the growth rate from 10 to 20 % over that of the controls, according to different factors which will be analyzed later. Such increase enables the animal to reach market weight earlier, with a corresponding saving in costs.

b) They provide a higher efficiency in feed conversion of approximately 5 %, although in some cases increases recorded have been as high as 11 %.

c) They reduce the incidence and seriousness of intestinal disorders (non-specific enteritis) which have a very marked effect on production costs, especially in swine breeding.

d) They reduce the number of weaklings and sickly animals in the farrows, providing an improved appearance and uniformity of the whole

litter, while diminishing mortality rate, feed waste and danger of disease outbreaks.

e) The most active antibiotics for pig breeding are quoted in decreasing order of importance:

Chlortetracycline (aureomycin).  
Oxitetracycline (terramycin).  
Penicillin.  
Bacitracin.  
Streptomycin (under certain conditions).

f) There is no special indication, their effect being practically null, regarding chloromycetine, neomycin, polymixin and subtiline. Some of these substances have been recently tested, e. g., carbomycin, oleandomycin, spiramycin and erythromycin.

g) The proportion generally recommended is 10 grams of antibiotic activity per metric ton of feed, as regards cyclines. The following doses may be considered as optimum:

|                                                                                          |                                |
|------------------------------------------------------------------------------------------|--------------------------------|
| Pigs in advanced stage of development; growing                                           |                                |
| pigs ... ..                                                                              | 10 grams per metric ton.       |
| Breeding and re-breeding pigs ... ..                                                     | 15 to 20 grams per metric ton. |
| Parturient and lactating sows ... ..                                                     | 10 to 20 grams per metric ton. |
| In all cases of malnutrition and defective conditions, the minimum dose should be ... .. |                                |
|                                                                                          | 25 grams.                      |
| Initial rations; milk replacers ... ..                                                   | 30 to 50 grams per metric ton. |
| Supplements ... ..                                                                       | 50 to 60 grams per metric ton. |

No detrimental effects have been reported. Also, no residues have been found in the tissues, even with 50 mg. levels of terramycin per metric ton of feed (Luther); the omission of its administration in the feed determines an immediate elimination in the tissues; on the other hand, the cooking process eliminates any traces of the product.

Aureomycin improved feed palatability; terramycin and penicillin did not show any effect in this direction, while erythromycin gave an opposite effect (Tomlin, 1958).

i) Antibiotics do not have any deleterious effects through several generations, nor affect the final size of the animal. It has been pointed out that the change in intestinal bacteria might be a disadvantage for the natural development of immunity against certain infectious diseases.

The *response to antibiotic supplementation* may be influenced by the following factors:

1. Feed Factors:

a) Quality of ration used; the response to diets lacking animal proteins is generally more pronounced. Actually, in Spain, and in most European countries, the rations generally used have rather high levels of animal protein content.

It appears that the beneficial effect is higher in pigs fed with dry food rather than pasture fed. The decrease of protein rate in the ration is very significant from the zootechnic point of view.

b) When using high level supplements (from 50 to 200, and even as high as 1000 grams per metric ton) for therapeutical purposes, it is especially



necessary to consider the presence of inhibitor factors; calcium salts play a very important role in this sense, as such salts are a normal supplement; their inhibitor effect depending on their source and level in the ration.

The rate of inhibition increases in relation to the different antibiotics, in the following order: penicillin, oleandomycin, chlormycetin and bacitracin; oxi- and chlortetracycline, streptomycin and neomycin. Discontinuous administration is recommended, alternating with low levels of calcium supplementation.

c) Similarly it is necessary to take into account the presence of potentiators: tereftalic acid, in 0.4 to 0.5 % levels acts as a potentiator, improving oxi- and chlortetracycline absorption and diminishing the rate of renal elimination; this action adds up to the effect obtained by temporally reducing the calcium level in the ration.

In this direction, new developments permit increasing the level of antibiotics both in blood serum and tissues, which is a very important application from the standpoint of quality and commercial life of foods.

d) Synergy with other additives: for example, the added effects of oxitetracycline and dietilestilbestrol. The presence of vitamin B<sub>12</sub> also potentiates antibiotic action. There is no conclusive evidence of a higher action or effect of mixed antibiotics against isolated administration; nor any effects have been found on the action of coccidiostatics, for example, by addition of oleandomycin.

2. Age of the Animals. The younger the animals the higher the effect, excepting the initial phase of lactancy. Nevertheless, to derive the maximum benefit from antibiotic administration it is necessary to extend its administration during the whole breeding period.

No marked effects have been found on:

a) Quality of descent when administered to breeder cattle. Generally, no increase has been observed in the number of piglets in the litters, weight at birth nor any other variation in the number of piglets dead at birth. Several observations register piglets a little stronger and heavier, especially at weaning, with a higher uniformity in the litters (Sewell, 1958). They may be of value in certain cases of stress factors, such as disease level, quality of rations and other adverse environment conditions.

b) Milk production of parturient sows; the milk does not receive amounts of antibiotics capable of producing any effect on the piglets.

The main application found for the use of antibiotics in pig breeding is in the formulation of special rations for the early weaning of piglets, and for the preparation of artificial milks.

3. Environmental conditions (other than feeding). It appears an established fact that antibiotics have a very low effect in hygienic environments, where no pigs have been raised before. Therefore, it seems that the level of disease or degree of contamination of the animals has a very marked influence in this condition.

The seemingly decrease of antibiotic effect during recent years appears to be caused by an improvement in sanitary conditions and a corresponding reduction in the level of disease, and by the general use of more efficient methods of nutrition, as compared to the methods in practice at the beginning of antibiotic application. This development may be also due to the fact that antibiotics are now used quite early in the life of the animal and, therefore, the



response at a more advanced age should be lower; in many cases, too, this development may be determined by the interference of inhibition factors, specially by high proportions of calcium in the rations. It has been also suggested that resistant bacteria may generate increasing amounts of growth factors.

4. Method of administration. Oral administration is the method to be used for obtaining a growth stimulating effect, by incorporation in the feed, implant administration or intramuscular administration, or high levels of antibiotics of easy absorption in order to obtain a given concentration in sow milk, thus conferring a more efficient protection to suckling pigs before they are given solid foods.

### ANTIBIOTICS EFFECT ON CARCASS QUALITY

It has been verified that, generally speaking, antibiotic administration does not have any bearing on carcass quality save by a slight increase in adiposity, non-significant in most cases. Even then, it appears that such increase is not caused by any specific effect as such, but rather due to the fact that market weight is reached at an earlier date; therefore, this increase in adiposity can be considered as an indirect effect of faster growth rate and higher feed consumption.

Even when the results do not agree, the increase of fat in animals receiving antibiotics seems to be dependant on the administration method used — limited or «ad libitum» — and protein level of the ration. «Ad libitum» feeding seems to increase fat percentage of carcasses.

In rations with low protein levels which produce carcasses with higher fat content, antibiotics do not exert any favourable effect for reducing fat production either; therefore, the recommendation that protein levels can be reduced through the use of antibiotics should be given careful attention before being applied.

Antibiotics do not modify carcass length, but they bring about a significant improvement in performance. They do not interfere with vitamin B supply in the carcass.

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It has been recently indicated that certain types of substances with surface activity have a favourable influence on animal growth, similar in effect to antibiotics.

We will refer specifically to tetra alkylammonium stearate, given in 1 % proportion in the feeds, on the basis of a compound containing 2 % of active principle; although the results obtained do not completely agree in all cases, it seems that this product provides both a stimulating action on growth and a control of certain affections of the digestive tract.

We have been able to observe this growth stimulant activity during a test performed on two lots, control and subject, of 120 and 172 animals, respectively, from 2 to 3 months old, for a 30-day period. The results obtained were as follows: an overall liveweight gain of 1,768 kilograms in the control group against 2,802 kilograms for the group fed tetra alkylammonium stearate, with conversion efficiency of feed used of 3.72 kilograms for the control group as compared to 3.5 kilograms for the second group, which means, percentage-

wise, an economy of 5.9 in feed utilization in favour of the experimental group, in addition to the beneficial effect on shortening the production cycle. The average total gain of the pigs from the experimental group was 16,500 kilograms, as against 14,600 kilograms for the control lot, with an average daily gain of 520 grams for the first lot and 488 grams for the control group. As a result of several difficulties inherent to control data recording it was not feasible to determine the degree of importance of such data.

The second practical test was performed with 113 lactating piglets, belonging to 17 sows (6.6 piglets per sow), housed in pens which had been in use for several years, always with exactly the same results: outbreak of diarrheas on the first or first and a half month, which subsequently developed into hemorrhagic diarrheas to become more acute at weaning; such diarrheas did not slow down until the pigs were three to four months old, with a very high proportion of deceases and irretrievable growth losses. Tetra alkylammonium stearate administration was initiated a month from birth, leaving a control group made up of 23 piglets; the pens were thoroughly disinfected. The diarrhea which some piglets had developed disappeared, and did not return during the observation period (until 6 months of age). These results have permitted the administration of feeds with a high protein content (20 %) to the piglets from the very beginning, which before was out of the question because of the high incidence of diarrhea produced by the pigs' feed proteins.

It would be very interesting to perform further trials under rigid experimental conditions in order to establish the real value of this and other similar agents.

Antibiotic administration, supplemented by up-to-date selection practices, improvement in sanitary and housing conditions has contributed to an effective improvement in pork production, due to the following reasons:

1. Improvement of sanitary conditions, reducing levels of disease.
2. Cutting down on pig losses through a reduction of mortality rates, a higher uniformity in the litters and possibility of extended use of artificial lactancy.
3. Improved feed utilization.
4. Shortening the production cycles.

## DISCUSSION

*Dr. Maddy (U. S.).* I would like to know whether you have any information as to the possibility of soybean feeding, regarding its lysine content, which seems to provide more favorable figures when feeding is intensified by using this aminoacid.

*Dr. Hanson (U. S.).* Supplementing lysine to a piglet ration containing a high amount of soybean and corn provides a rather high increase in growth. This seems to indicate that piglets are unable to assimilate soybean proteins as easily as milk proteins, this being the reason why piglet growth improves when feed lysine supplemented rations previous to weaning. In my opinion, after weaning, added lysine does not have any effect in this direction.

*Dr. Maddy (U. S.).* I would like to ask a general type of question regarding diet composition as related to carcass and skeleton quality. We have experimented with typically «fatty» pigs, feeding them high proteing levels, at the rate of 21 % from weaning to 16 weeks and 200 pounds of weight;



making a thorough analysis of carcass we have observed that it was of the «fatty» type, for which reason the animals were rejected. Is there anybody who thinks that this type of rations (that only had a 7 % of fat) have any commercial possibilities, regardless of genetics?

*Dr. Hanson* (U. S.). We too have made a number of studies with different protein levels, with mixed rations and with soybean and corn rations, without adding fats. For this reason, we believe that, in order to obtain a leaner carcass (regardless of the genetic factor which makes some breeds more fit than others for this purpose), and according to data compiled by Mac Melan (Cambridge) and Hamont and the results obtained by Danish workers using restricted caloric ingestion, we should feed pigs rather low amounts of proteins, instead of too many proteins. The trend to produce lean carcasses starts to diminish with rations having a 14-15 % protein content. 18 % gives too much fat already.

*Dr. Maddy* (U. S.). I should like to further comment on this subject, as I do not know whether I have put my question clearly enough. The diet I mentioned was supplied during all the time and everything went fine as long as weight was within 75 to 150 pounds. I believe, even if we have not made such test, that could we develop some kind of combination protein-calory we would be able to obtain a lean pig regardless of breed used, and that a genetically lean pig would be leaner than the genetically «fatty» pig. Of course, this might belong more to the field of genetics than to that of nutrition.

*Dr. Varela* (Spain). When determining the nutritive needs of calcium in pigs the metabolism balance technique is used, as you all well know. When we try to use this method we meet with a great difficulty to establish minimum calcium requirements as vegetable diets have, naturally, precipitators of the citrate and oxalate type. Our question is, whether or not this lack of correlation between ingestion and calcium could be related in any way to the findings of Ritter with ruminant cattle, and whether or not complexone utilization would be interesting for modifying these abnormalities found in calcium digestibility. Therefore, I would like to know if there is any additional information on this subject which we do not know yet.

*Dr. Hanson* (U. S.). I am not sure that I have understood this question properly; however, I might say that the studies on calcium for piglets which I mentioned during the slide projection are based on corn and soybean meal rations for half of the proteins and some milk; calcium levels are obtained by adding ground limestone to the diet. There is, as shown by the X-ray plates presented, a certain relationship between calcium levels, amount of ashes and resistance to bone fracture. 1 % levels produce stronger bones than 8 to 10 % levels. I do not know whether this answers Dr. Varela's question.

*Dr. Varela* (Spain). I am glad about this information, as it justifies my question. What I really wanted to ask is if there is available any information as to whether or not the experimental difficulty of finding out calcium needs could be related in any way to the existence of the precipitators I mentioned before as existing in the diet which inhibit digestibility and absorption; this is true in the case of ruminants.

*Dr. Hanson* (U. S.). We do not seem to have any problems with calcium, inasmuch as the low price of limestone enables us to use it for supplementing soybean and corn rations. Therefore, we have not tried to examine the



technical or physiological aspects of what happens with such calcium, nor have we conducted any research on balance studies regarding calcium retention.

*Dr. Varela* (Spain). Breeding of swine with little exercise, a method which is becoming to be known as «battery system» has doubled the normal coefficients of transformation. Up to now, this type of research has been limited to digestibility tests. Could you tell me if this type of tests have been initiated on an industrial level?

*Dr. Hanson* (U. S.). Some 15 years ago I worked with «battery pigs» as they are called now, these pigs only moved to go to the scales placed at a distance of 70 feet from the pigs. The results were not too satisfactory because subject pigs were not normal animals, due partly to the fact that we did not give them very exact rations (of course this would not happen to-day). At the present time, this type of pig raising is being contemplated in the United States. Dr. Logan, from Nebraska, has already performed a lot of work in this direction. Dr. Logan has established a formula for the first weeks with milk and calcium supplemented by iron and other minerals, also maybe with egg and some vitamins; after 4 to 5 weeks, the pigs are taken to the farm and administered a feed with a good proportion of milk up to 8 weeks of age.

As to the question about whether or not the battery system is a practical one, I am of the opinion that it is not, unless highly precocious breeds are used, because it is too expensive. These pigs are sold in the United States at about 40 or 45 dollars.

*Dr. Varela* (Spain). Thanks for your highly informal answer, Dr, Hanson. I would like now to emphasize the importance of Dr. de Juana's work on animal feeds. In the Mediterranean olive growing areas a serious problem is encountered regarding swine breeding because of the energetic deficit, which can be corrected by supplementing the feeds with olive fats, even though this fat has a very high fatty content, above that of the maximum required for normal or regular rations. Our research coincides with Dr. de Juana's work, however we find that at the present time this system is not economical, apart from other considerations. Nevertheless, we repeat that Dr. de Juana's work is extraordinarily interesting for the economics of our olive producing areas.

*Dr. Ludvigsen* (Denmark). I would like to refer to the previous comments regarding balance technique. We do not use it because we have found that the more calcium we feed to our pigs, the more they retain; it appears that tension is due to sediments of calcium in form of crystal on the inner and upper parts of the osseous epiphys.

I also would like to ask Dr. Maddy, with reference to lean pigs, about the specifications for rejecting lean meats not according to the consumers' taste.

*Dr. Maddy* (U. S.). The test was performed by a specialized organization. Their report stated that the animals were exceedingly lean, their meat was too dry and did not taste well. Therefore, we consider that the American consumer likes a little fat in his pork, but not too much. Therefore, it is necessary to produce a pig that is not either too fat or too lean. Here, as everybody will understand, lies one of our greatest problems. We have to try and come up with the type of pork required by Mrs. Consumer, but we have no way of knowing what she exactly wants. We believe that nutrition and genetics are the answer to produce this pig.

*Dr. Stockstad* (U. S.). Regarding battery pig breeding we might say that

it is increasingly necessary that pigs do not utilize too much. In the United States, where pigs are raised in the country, it is necessary to give them iron, either by injection or orally, from time to time; I think this means an important difference between battery fed pigs and pasture pigs. I would also like to say a few words as to the calcium level that should be used. It is quite possible that a calcium level of up to 1 % will result in greater bone strength; however, pigs should also be given antibiotics for epizootic prevention. This will result in antibiotic absorption, and this is the reason why it may be necessary to reduce calcium level down to 0.4 % when antibiotics are administered. For poultry, this level is about 1 % or less when using antibiotics.

MODERATOR. I think we have run out of questions. Any more questions about this subject?

Well, then I will make my little contribution to this interesting matter.

Summing up, it appears from what has been said this morning that pig breeding, no matter where, presents a problem of quantity and a problem of quality. These problems are not necessarily connected. Everything seems to indicate a trend towards leaner pigs than the ones produced heretofore with organoleptic characteristics that satisfy the consumer. Then, the problem may be stated as follows: it is necessary to learn the influence of ration composition on the basis of the chemical composition of the tissue; of course, this last factor cannot provide all necessary information regarding quality, taste, etc. Therefore, there is ample room for personal and subjective appreciation. All means for growth stimulation are useful; as we said before, we should not underrate feeding problems but we should not forget either the genetic factor, fat, selection, etc. If we stimulate growth the pigs will reach their optimum weight earlier; then we need not be afraid that the quality of their meat be different or lower than meats from a more mature animal. Of course, there is a maturity of meats in function of the animal's age which nobody can deny, in pigs as well as in poultry.

Regarding antibiotics, the problem has been very well presented; probably, there is still a lot to add with respect to antibiotic action. There are some facts, however, that cannot be discussed. These factors refer to the influence of hygienic conditions in animal breeding. A good number of tests indicate that very frequently, the favorable action of antibiotics does not take place in aseptic surroundings. It can be admitted that antibiotics do not have a marked effect on the chemical composition of the meats produced, even if some of them may have resulted in some modification in laboratory specimens. As regards tensioactive substances, I do not quite agree with the speaker on their favourable action; of course, there may be differences according to the different countries.

Along these lines I could speak about the favourable effects of copper sulfate. Finally, and referring to the calcium balances I think this is not, evidently, a good technique, as there are many factors which motivate calcium reabsorption. I also believe in the need for more refined methods and that feeding conditions play a very important role (phosphorous content in the rations, vitamin B content, etc.) and interaction between antibiotics and the type of calcium used.

Now we leave the floor to Dr. W. M. Beeson, who will talk about «Ruminants: Recent trends and Developments in the United States».



## RUMINANTS: RECENT TRENDS AND DEVELOPMENTS IN THE UNITED STATES

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Science and technology are rapidly replacing the «art» and «eye» of ruminant nutrition. Each day new facts are revealed which unfold some of the mysteries of the ruminant animal. Properly supplementing ruminant rations is becoming as complex in the United States as poultry and swine diets. Nutritional and other developments in ruminant feeding progressed rather slowly until scientists started probing for the nutrients synthesized by the microbial life in the rumen. There is no doubt that the rumen is the greatest natural synthesizing plant on the earth for vitamins, protein and unidentified factors. These basic discoveries led to a new concept in ruminant nutrition showing that part of the «key» to the proper nutrition of ruminants — beef cattle, dairy cattle and sheep — was to provide the necessary nutrient to increase the synthesizing power of the microorganisms in the rumen.

Equally important to the nutritional advances in the past 20 years is the effect of certain feed additives such as antibiotics and hormones on the performance of cattle and sheep.

This paper will summarize briefly the present status of the following nutrients and feed additives for ruminants; namely, (1) antibiotics, (2) chem-biotics, (3) ethanol, (4) hormones, (5) goitrogenic agent (tapazole), (6) enzymes, (7) tranquilizers, (8) urea, (9) amino acids, (10) vitamin A, (11) dehydrated alfalfa meal, (12) pelleting and (13) low roughage feeding.

### ANTIBIOTICS

Over the past six years more than 130 experiments have been reported on the effect of antibiotics on beef cattle. To date a majority of the tests have indicated that aureomycin (chlortetracycline) and terramycin (oxytetracycline) are the most effective antibiotics for improving the performance of beef cattle. The response to antibiotics varies with the energy level of the ration, feedlot conditions and disease level of the cattle. Under certain feeding conditions, especially on high roughage diets, the oral feeding of 70 to 80 milligrams of either aureomycin or terramycin will increase gain, feed efficiency, carcass quality and health of cattle. On an average antibiotic will improve gain and feed efficiency 4 % on fattening rations and about 8 % on growing



rations. It cost less than 1 cent per head daily to feed an antibiotic, and the return per dollar invested is about threefold. In addition, there are many unrecorded values which cannot be measured in terms of extra weight and feed saving. In the United States antibiotics are most often used in commercial feedlots and are now being accepted by the most discriminating cattle feeders.

When antibiotics are fed alone, there is no change in carcass quality; but antibiotics definitely improve carcass grade when fed with stilbestrol. Numerous experiments have shown that a combination of an antibiotic and stilbestrol is superior to stilbestrol alone, especially, from the standpoint of carcass quality. Tests at Purdue (Beeson *et al.*, 1956) have shown that feeding a combination of an antibiotic and stilbestrol upgraded the carcass grade from 47 % choice (no antibiotic) to 72 % choice carcasses.

The narrow spectrum antibiotics, such as penicillin and zinc bacitracin, have not been beneficial in stimulating gain or saving feed for beef cattle (Perry *et al.*, 1954; Beeson *et al.*, 1960). However, mixtures of equal parts of broad and narrow spectrum antibiotics have given essentially the same results as a single broad spectrum antibiotic such as aureomycin. Preliminary research on the use of ilotycin in rations for calves has shown only a slight beneficial effect.

Burroughs *et al.* (1960) of Iowa have reported that supplementing a wintering ration of corn silage, limited grain and hay with either 75 mg. of aureomycin or erythromycin per steer or heifer daily increased daily gain about 14 percent and improved feed efficiency 11 to 13 per cent. This improvement was over and above the stimulation by stilbestrol. No significant effect was obtained from penicillin.

A recent report from the Kentucky Experiment Station has shown that a combination of terramycin and stilbestrol implant is superior to stilbestrol alone for steers grazing on pasture. Terramycin was fed in the salt at a rate of 80 milligrams per head daily. The control steers gained daily 1.07 lb., 24 mg. stilbestrol implant 1.37 lb., and stilbestrol plus terramycin 1.59 pounds. On an average, terramycin produced an additional gain of 0.22 pound daily.

Antibiotics are also used effectively at high levels (350-500 mg. per head daily) to control shipping fever in the United States. Many conditioning feed supplements are now being manufactured to be fed for 7 to 21 days after cattle arrive on the farm. Although this does not entirely prevent the onset of shipping fever, it tends to reduce the severity. Also, water soluble preparations of antibiotics are being used in the drinking water for the control of shipping fever.

## CHEMBIOTICS

Conflicting data have been published on the reaction of beef cattle to the feeding of tetra alkylammonium stearate (Dyna-fac). «Dyna-fac» is a trade name for a product containing 20 % tetra alkylammonium stearate and 80 % bonemeal. In some experiments, especially under western cattle feeding conditions, significant stimulation has been obtained by feeding 1.0 to 2.0 grams of this chembiotic (Dyna-fac) per animal daily. However, most midwestern experiments have shown no significant response from feeding tetra alkylammonium stearate.

In Iowa experiments (Burroughs *et al.* (1958) it was shown that fortifying a supplement with Dynafac (1.0 to 2.0 gm. daily) with or without stilbestrol failed to alter the liveweight gains or feed per unit of gain. Feed costs of gains were increased and carcass grades lowered by the Dynafac additions. At Illinois, Neumann *et al.* (1958) found no beneficial effect from feeding 2.0 gm. of Dynafac to yearling steers either stilbestrol treated or not treated.

In Montana (Thomas, 1958), the addition of Dynafac to a growing ration for steers increased the daily gain 16 %, and a combination of Dynafac and terramycin increased the gain 28 percent. In two other trials, Thomas *et al.* (1957) showed a response from feeding Dynafac to yearlings on a fattening ration in drylot and also when steers were self-fed a concentrate mixture on pasture. At Washington State College, Dyer *et al.* (1958) obtained a slight increase in the daily gain of steers fed on Dynafac.

### ETHANOL (ETHYL ALCOHOL)

A report in 1956 that a mixture of molasses, urea, minerals, ethanol and vitamins made an effective supplement for balancing the rations of beef cattle stimulated research to measure the effect of ethanol upon urea utilization. In a nitrogen balance study at Cornell University (Loosli *et al.*, 1958), ethanol increased the retention and biological value of nitrogen of a ration containing poor grass hay, molasses, urea and minerals to about the same extent as an isocaloric amount of starch. Research at Kansas with beef heifers indicated that feeding ethanol in conjunction with a molasses-urea mixture did not improve gain, feed efficiency or carcass quality. At Kentucky dairy heifers gained 0.80 lb. daily on a ration of corn cobs fortified with a supplement of molasses, urea and minerals and 0.73 lb. daily when 6 % ethanol was added to the mixture. In four comparisons at Iowa (Burroughs *et al.*, 1958), adding 3 ounces of ethyl alcohol per steer daily to a fattening ration of ground ear corn and supplement resulted in a slight increase in daily gain (0.11 lb.) and a 3 % improvement in feed efficiency.

A report from Louisiana (Nipper and Robertson, 1959) has indicated that ethanol will improve nutritional value of a molasses-urea liquid supplement when used to balance a low protein-low starch ration consisting of cottonseed hulls.

Since the effect of ethanol has been variable, additional experiments need to be conducted to clarify the effect of ethyl alcohol in cattle rations.

### HORMONES

Only two synthetic hormone preparations have been approved as a growth stimulant in cattle; namely, diethylstilbestrol implants and oral feeding. Both of these methods are doing an excellent job of increasing daily gain and improving feed efficiency in beef cattle. Extensive research has shown that implanting and oral feeding of stilbestrol are equally effective in every respect in dry lot. It is a matter of personal choice as to which method is used. On pasture either with a full-feed of grain or with limited grain, oral stilbestrol



is not effective; but implanting steers with 24 mg. of DES at the base of the ear gives excellent results on pasture.

Basic research has shown that two other similar hormone-like substances, dienestrol and hexestrol, will give the same improvement in gain and feed efficiency when fed orally as diethylstilbestrol. Hexestrol is widely used in England and has less side effects than diethylstilbestrol. Many natural plant hormones are being studied which may have a practical application to feed lot operations. U. S. D. A. workers have isolated coumestrol, an oestrogen from plants. Matsushima at Nebraska (1959) has shown that dehydrated alfalfa meal fed at a level of 3.0 pounds per head daily will give essentially the same growth stimulation and improvement in feed conversion as 10 mg. of stilbestrol. In the near future now hormone preparations, both natural and synthetic, will be available for cattle feeding.

### GOITROGENIC AGENT (TAPAZOLE)

Tapazole (1-methyl-2-mercaptoimidazole) is a very potent antithyroid agent and is used to treat hyper-thyroidism in humans. Several experiments from Iowa (Burroughs *et al.*, 1959a, 1959b, 1960) have indicated that feeding 300 to 600 milligrams of tapazole per steer daily would stimulate liveweight gains in cattle (8 %) and improve feed utilization (7 %) for relatively short periods (60 days). In contrast, research at Illinois (Neumann *et al.*, 1958; Mitchell *et al.*, 1959) resulted in a stimulation in gain from tapazole the first 28 days; but during the remainder of the test, the steers receiving tapazole were out-gained by the control steers. The net result being a reduction in daily gain from feeding tapazole. In a feeding test with yearling steers, Missouri workers (Thompson and Comfort, 1959) showed that feeding 300 mg. of tapazole the last half of a 126-day fattening period did not significantly improve gains, feed efficiency, selling price or carcass grade.

The use of tapazole as a feed additive for cattle is still in the experimental stage. If it has any value, it will be only for short feeding periods.

### ENZYMES

One of the newer innovations in feed additives for beef cattle is research on the use of proteolytic and amylolytic enzymes as a growth stimulant. Burroughs *et al.* (1959, 1960) reported that feeding an enzyme (Agrozyme) at a level of 0.0075 pound daily to cattle on low-moisture corn (14 % or less) will stimulate liveweight gains about 12 %, increase feed intake 4 %, and improve feed efficiency 7 percent. In contrast, in the Iowa tests, no benefits were obtained from enzymes fed to cattle on corn containing 19 to 30 percent moisture. A recent study by Mitchell *et al.* (1959) has shown that feeding an enzyme (Agrozyme) to cattle on a ration of ensiled shelled corn and alfalfa (40:60 mixture) had no significant effect on gain or feed conversion fed singly or in combination with tapazole. Several tests by Beeson *et al.* (1959) on different enzyme preparations (Agrozyme, Diazyme, HT-550F and Zymo-Pabst) have shown that the feeding of enzymes to steers in drylot on a



fattening ration of low-moisture corn (full-fed), 2.0 lb. supplement and 17.0 lb. corn silage had no significant effect on gain or feed efficiency. Perry *et al.* (1960) reported no benefit from feeding Agrozyme, Diazyme or HT-550F to cattle fattened on either low- or high-moisture corn. In tests at Minnesota, Meiske *et al.* (1959) observed that steers on certain rations fed Zymo-Pabst gained faster (5 %) on less feed (4 %) than the no enzyme groups. However, in this experiment the performance of cattle full-fed on shelled corn containing less than 14 % moisture was not improved by enzyme supplementation. Daily gains and feed efficiency were improved in the two groups of cattle fed on ground ear corn or a combination of shelled corn and fat. Burroughs *et al.* (1960) observed fairly good results by feeding an enzyme Ficin.

In general, the results reported to date on the use of enzymes as a feed additive for beef cattle are conflicting and inconsistent. Apparently the type of ration has a marked influence on the response of cattle to enzyme supplementation. It is quite obvious that the true effect of enzymes on the ruminant is in a state of uncertainty. On account of this fact, more research needs to be conducted on a fundamental basis to determine the true function of enzymes in ruminant nutrition.

## TRANQUILIZERS

Traquilizers, such as hydroxyzine, reserpine, rauwolfia and trifluomeprazine, have been tested experimentally as growth stimulants in cattle. However, the levels used as a feed additive are usually not high enough to cause any noticeable calming effect. A review of 80 experiments indicates a variety of results, but a majority of the tests shows very little if any effect on improving gains or feed efficiency.

In some of the earlier experiments, feeding 2.5 mg. of hydroxyzine daily to steers in combination with terramycin and stilbestrol gave a significant improvement in liveweight gain and feed conversion. Later research failed to confirm these initial findings. Recent research reports from Indiana, Iowa, Kansas, Michigan, Minnesota, Nebraska, Montana and Oklahoma have indicated that the feeding of tranquilizers, such as hydroxyzine, reserpine and trifluomeprazine, was of no significant benefit for fattening cattle. Feeding hydroxyzine to cattle at the Kentucky and Texas stations has given positive results.

From the research reports published to date, it appears that response of cattle to feeding tranquilizers is inconsistent; and their value as a feed additive is questionable. New tranquilizers are being tested which may have a potential value.

Tranquilizers have their greatest potential value as therapeutic injections to reduce the stress periods in animal life such as (1) reduction in shipping shrink, (2) elimination of shock of weaning calves, (3) relieving tension and anxiety during certain operations such as dehorning, clipping, castrating, branding, etc., and (4) to pacify nervous animals at parturition.

## UREA

The use of urea to meet part of the protein requirements of ruminants—beef cattle, dairy cattle and sheep—is increasing and will continue to expand as we learn more about the nutrients required for microbial synthesis of protein from urea. Last year over 75 thousand tons of urea were used in ruminant rations, and in 1957 only 64 thousand tons were fed—a 15 % increase in a short span of two years.

The limiting factors in the use of urea are not the supply or the cost but the lack of basic knowledge on the nature of protein synthesis by microbial life in the rumen and the nutrients required—both qualitative and quantitative—for maximum production. We must find the answers to the simple question, «Does a ruminant have the potential to synthesize more than one-third of the protein needs from urea?» When we unlock the secrets of protein synthesis in the rumen, a majority of the supplementary protein (50-75 %) can be furnished by urea.

### *What is Urea? How Does It Function?*

Urea is a simple non-protein organic compound which contains as a commercial preparation 42 % nitrogen and is potentially equivalent to a 262 % protein feed. However, urea alone has no protein value for livestock. Bacterial protein of good quality is formed in the rumen by bacterial synthesis and is subsequently digested by enzymes in the stomachs and intestines of the host animal. Bacterial protein is then metabolized and synthesized into body protein in the form of meat, milk and wool. Urea has no practical function in monogastric animals.

### *Nutrients Required for Protein Synthesis*

All of the essential nutrients both major and minor are not known. Some of the well-known critical nutrients that should be supplied in a protein supplement or complete ration containing urea are as follows:

1. Adequate level of starch feeds, such as corn, milo, hominy, etc., to supply energy. On the basis of nitrogen and energy value, 6 pounds of corn and 1 pound of urea are equivalent to 7 pounds of soybean oil meal.
2. Sugars (glucose, sucrose, molasses) are inferior to starch for urea utilization.
3. Provide an adequate level of available phosphorus.
4. Fortify with trace minerals but do not use excessive amounts.
5. Include dehydrated alfalfa meal (5 to 14 %) to supply sources of unknown protein synthesis factors.
6. Avoid the use of high fiber «filler feeds» such as screenings, oat hulls, corncobs and the like to replace the energy lost by replacing soybean, cottonseed or linseed meal with urea.
7. A good urea supplement must contain as high quality ingredients and essential nutrients as a protein supplement made up entirely of natural proteins.



### *Safe Levels of Urea to Use*

When fed at the proper daily level to cattle, urea is an excellent source of crude protein; but when fed at excessive levels, it is toxic. For maximum performance, the intake of urea for cattle should not exceed 0.2 pound per head daily or not more than one-third of the protein requirement. The daily intake is the «key» to the formulation of urea feeds, and not the percentage. For example, you can feed up to 4.0 pounds daily of a supplement containing 5 % urea but not more than 2.0 pounds of a supplement with 10 % urea. Therefore, it is difficult to set down «iron clad» rules for urea formulation on a percent basis.

The following recommendations are safe and give good performance if the daily feed recommendations are proper:

| Type of Ration            | Urea<br>% | Maximum<br>Daily Feed<br>lb. |
|---------------------------|-----------|------------------------------|
| Complete Ration (Air Dry) | 1.0       | 20                           |
| Grain Ration              | 2.0       | 10                           |
| Grain Ration              | 3.0       | 7                            |
| Protein Supplement        | 5.0       | 4                            |
| Protein Supplement        | 10.0      | 2                            |

### AMINO ACID SUPPLEMENTATION OF UREA

A majority of the mixed protein supplements fed to cattle have 30 to 32 percent crude protein. Recently there has been a lot of interest in compounding supplements with high levels of urea (10 % or more) containing 48 % to 56 % protein. Research at Purdue (Perry *et al.*, 1960; Beeson *et al.*, 1960) has recently shown that feeding 1.33 lb. of a 48 % supplement (7.5 % urea) or 1.14 lb. of a 56 % supplement (11.1 % urea) does not give the same nutritional value as 2.0 pounds of a 32 % supplement made from natural proteins. The 32 %, 48 % and 56 % supplements were fed on the same protein equivalent basis. Lysine was found to be the limiting factor. Urea supplements ranging in protein equivalent content from 40 % to 72 % were equal in feeding value if 10 grams of lysine was fed per steer daily. Methionine gave no effect. In simple terms, 1.0 lb. of a 64 % supplement (15 % urea) with the amino acid lysine is equivalent in nutritional value to 2.0 pounds of a 32 % protein supplement (Purdue Supplement A) made from natural proteins. When the new 64 % supplement is perfected, it will be known as «Purdue 64 Supplement.»

Sherman and co-workers (1960) was the first worker to show that the performance of lambs and cattle could be improved by the feeding of lysine. According to them, it is not known whether the amino acids are acting



simply to supply a nutrient need *per se* or whether the free amino acids stimulate bacterial synthesis.

Although all of the essential amino acids (components of protein) can be synthesized in the rumen by microorganisms from urea, at least one is limiting — lysine. There may be others. *This opens a new frontier in ruminant nutrition and paves the way to a larger use of urea.*

## CAROTENE VS. VITAMIN A FOR BEEF CATTLE

Vitamin A fortification needs more attention in cattle feeding. Old corn, poor quality hays, and overheated silages and grains are low in carotene (pro-vitamin A). Small grains such as oats, wheat, barley and milo contain no carotene (pro-vitamin A). Cattle require about 10,000 I. U. of synthetic vitamin A per day in addition to carotene from natural feedstuffs. Some beef cattle feeders in the U. S. A. are feeding 30,000 I. U. of vitamin A with excellent results. Something has changed the utilization of carotene by beef cattle. Perry *et al.* (1957) reported a vitamin A deficiency in cattle by self-feeding them on 8 parts of ground ear corn and 1 part of soybean meal. These cattle gained poorly (1.62 lb. daily) and lost \$9.38 per head, while similar cattle fed Supplement A which is fortified with vitamin A made a gain of 2.44 pounds daily and a profit of \$23.36 per head. Part of this difference in profit and loss was due to vitamin A.

Illinois workers (Neumann, 1960; Mitchell *et al.*, 1960) have reported an occurrence of vitamin A deficiency in beef cattle on rations that are more than adequate in carotene, the precursor of vitamin A. In these studies synthetic vitamin A was twice as effective as pro-vitamin A from alfalfa meal. In basic studies Pfander of Missouri (1960-unpublished) has made similar observations. Beeson (Purdue 1960-unpublished) has shown that yearling steers on a self-fed ration of 8 parts of ground ear corn and 1 part of soybean meal and minerals require 16,000 to 32,000 I. U. of synthetic vitamin A palmitate per head daily for best results. Also, observations on these cattle during hot weather (90 degrees Fahrenheit) have revealed that the cattle on the higher levels of vitamin A (16,000 to 32,000 I. U. per steer daily) suffered less from the heat from the standpoint of bodily comfort and appetite. Later in moderate weather (50 to 60 degrees F.), these differences were not noticeable. In Canada, Williams (1960) obtained a significant increase in daily gain of steers by increasing the vitamin A supplementation from 7,000 to 14,000 I. U. daily. The change in the status of carotene conversion to vitamin A in beef cattle is an intriguing phenomenon.

Scientists working on this vitamin A problem believe that the high nitrogen fertilization of crops produced in the Midwest has increased the amount of free nitrates and nitrites in our farm grown grains and forages and that the nitrates and nitrites interfere with the conversion of carotene to vitamin A in the animal body. Basic research with laboratory animals has clearly shown that nitrates and nitrites will inhibit the metabolism of carotene to vitamin A. Carotene has to be changed to vitamin A before the animal can utilize it. This means we may have to rely more and more on synthetic vitamin A until we learn how to correct this condition.

## ALFALFA MEAL (DEHYDRATED)

Dehydrated alfalfa meal (17 % protein) contains some unknown factor and/or factors which stimulates gain and improves the utilization of feed by cattle on both growing and fattening rations. Part of this is due to oestrogenic activity. Cattle require a minimum of 0.5 lb. of alfalfa meal per head daily, and many feeders are using 1 to 3 pounds of alfalfa meal or pellets to improve their cattle rations. This discovery has increased and improved the utilization of poor quality roughages in cattle rations. No longer do we have to depend on farm-produced hay of varying quality to furnish sources of unidentified factors for ruminants. Now we can produce and furnish a standard product. Dehydrated pelleted roughages of all types will be more abundant in the future. Weather will cease to play a part in preserving roughages.

## PELLETING

Research reports from several experiment stations have shown that the pelleting of poor grade hays and other roughages will increase the consumption by ruminants, improve the daily gain and feed efficiency. Tests at Illinois (Webb *et al.*, 1957) have shown that beef calves will gain 1.73 lb. daily on a pelleted hay and only 0.63 lb. on the same hay baled or chopped. Two hundred twenty pounds of beef were made from a ton of pelleted hay and 115 pounds of beef from a ton of the same hay baled. In general, pelleting hay crops will double their feed value for beef cattle. Pelleting high-energy diets has not improved the daily gain of cattle but, in some instances, has increased the feed efficiency about 14 percent. A test at Purdue (Perry *et al.*, 1958) has shown that the pelleting of a diet containing 70 % corn cobs and 30 % concentrate improved the daily gain from 1.57 to 1.98 pounds, and the steers on the pelleted rations required 14 % less feed per unit of gain. Similar diets containing 20 to 45 percent corn cobs showed no improvement in daily gain or feed efficiency.

There is a great interest in the pelleting of all types of roughages in the U. S. A. such as sorghum silage, corn silage, etc.; and many large feed lots will adapt this method for their cattle feeding operations. Pelleting has gained in popularity in the formation of supplements for beef cattle. Cattle will usually eat pelleted feed much quicker than they will meal, and also it permits the simultaneous feeding of nutrients in a condensed form.

According to a review made by Loosli (1959) on pelleted feeds for ruminants, «the use of wafered or pelleted forage for lactating cows has not increased feed intake or milk yields. When the hay has been finely ground before pelleting, the fat content of the milk is lowered and digestibility is depressed. The use of pelleted concentrates for dairy cows is increasing, and this trend will probably continue.»

Although the fundamental reason is not known, it appears that diets high in fiber are more adapted to pelleting than those high in energy. Condensing a bulky feed like hay allows the animal to consume more, permitting a larger intake of nutrients above maintenance requirements.



## LOW ROUGHAGE FEEDING

There is a possibility that the roughage requirement for fattening cattle may be lowered provided that the diet is well balanced. Specific nutrients are partially replacing the factors formerly supplied by high quality roughages. Whereby for rapid fattening we can feed cattle essentially on concentrates. Geurin *et al.* (1960) showed that steers or heifers can be fattened on a ration of 9 parts barley and 1 part of a well balanced mixed protein supplement without any roughage excepting the fiber furnished by the barley.

Recent fundamental discoveries have shown that one of the basic functions of roughage is to increase saliva flow which is rich in bicarbonates (Matrone *et al.*, 1959). Experimental cattle and sheep are being fattened now by substituting a certain percent of sodium and potassium bicarbonate for roughage. Maybe the sodium bicarbonate days will return. Even without bicarbonates, cattle are being fattened on barley and a well balanced supplement. A steer requires a minimum of 2 to 3 pounds of roughage (fiber) per head daily. Roughages are still a very important phase of cattle feeding; but at certain periods, we may want to speed up the rate of fattening after the roughage phase.

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## DISCUSSION

*Dr. Castella* (Spain). I would like to ask Dr. Beeson if there is really a lack of research studies on feeding of sheep cattle for increasing wool production, or on feeding of dairy cattle for increasing milk production as compared to the same type of studies on beef cattle. If this is the case, what are the reasons for this lack of research? Is it due to the belief that it is impossible at present to make any progress in this direction or rather because the U. S. breeders are not economically interested in any substantial increase of wool and milk productions?

*Dr. Beeson* (U. S.). I am not sure that I understand your question properly. I am no authority in the field of dairy cattle, because it is a more complex problem.

*Dr. Castella* (Spain). Another question, please. I would like to know whether in the United States you have seasonal differences in the utilization of alcohol in ruminant nutrition, i. e., during the summer and winter periods. In Spain we have sometimes found differences in the nutrition and therapeutical fields.

*Dr. Beeson* (U. S.). As far as I know, nobody has done any research in this direction in the United States. I should say that alcohol is more beneficial at low temperatures than in hot climates.

*Dr. Castella* (Spain). The negative results encountered in the use of tranquillizers refer only to beef cattle or can be understood as including dairy cattle, too?

*Dr. Beeson* (U. S.). All research work mentioned in my report refers to beef cattle, and not to dairy cattle. I cannot say whether this research would have any influence on secretion, as the experiments I mentioned have been performed on beef cattle only.

MODERATOR. Any more questions?

*Dr. Kon* (U. K.). First of all I would like to congratulate Dr. Beeson on his most interesting presentation. It is a real pleasure to listen to him.

Now, I would like Dr. Beeson to tell us something about the effects of triesterol on increasing nutritient content, what is his position in this respect, and what experiments have been made in the United States to increase bone weight in some other way.



*Dr. Beeson* (U. S.). All research activities conducted so far seem to indicate that this product results in skeletal and muscular improvement.

*Dr. Kon* (U. K.). We would like to know something as to the convertibility of carotene in the presence of great amount of corn seeds. I mean, whether in *Dr. Beeson's* opinion is it possible that the interference existing between inactive carotenoids might help conversion of active carotenoids.

*Dr. Beeson* (U. S.). I think you are right. There is the possibility that other inactive carotenoids may play a part in animal metabolism.

*Dr. Kon* (U. K.). One last question, which isn't really a question, because *Dr. Beeson* has already indicated that his record did not deal with dairy cow. However I would like *Dr. Beeson* to tell us whether he agrees that milk from cows fed low-vitamin rations is satisfactorily maintained.

*Dr. Beeson* (U. S.). I think I agree with that.

*Dr. Hillier* (U. S.). I hope you will excuse me for taking the floor at this time, as I have been appointed Moderator to another Panel; however, as a manufacturer of products intended for animal feed preparation I am extremely interested in *Dr. Beeson's* opinion regarding the reasons why certain hay concentrates produce a substantial increase in weight.

*Dr. Beeson* (U. S.). The only explanation there is for this gain is the following:

Hay-feed concentration permits the animal to eat more of the food in relation with its own weight; the quality is therefore improved as the animal eats more with less effort. However, this improvement has a limiting factor. If this concentrate is added to a high-quality diet there will be no improvement in the efficiency of gain increase.

MODERATOR. *Mr. Quintanilla* (Spain) will talk now about «Forages and concentrates in Beef Production».

## ✕ FORAGES AND CONCENTRATES IN BEEF PRODUCTION ✕

BY

C. F. QUINTANILLA

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One of the most characteristic problems in beef production in Spain, as in many other countries with great seasonal variation in forage production, is the temporary nutritional deficiencies shown by retardation of growth and even complete arrest of it during such periods.

We will comment briefly on a number of studies and tests we have carried out in connection with this problem.

It is obvious that an animal is more sensitive to improper feeding during the first few months of its life than at a later age. It is also at an early age when improper feeding can and usually produce the greatest harm.

The English research workers at the University of Cambridge, headed by A. J. Brookers, consider that in general, the nutritional deficiencies during the first eight months of life, in cattle, affect considerably their rate of growth and their characteristics of production not only in the aspect that could be



called morfological or of more or less suited conformation for the type of production being seeked, but also concerning the future capacity of the animals to transform the nutrients, that is to say their feed efficiency. This is true particularly in the case of coarse feed of poor digestibility.

The interesting studies with identical twins carried out by A. Hanson and coworkers in Sweden and by F. Winchester and coworkers in the United States, also agree in the considerable influence that the nutritional regime, especially the supply of energy, has upon the growth of the very young animal. Nevertheless their conclusions do not allow to attribute to these effects the same importance given to them by the English school.

We have observed in our tests that those animals receiving a minimum of milk and therefore submitted almost since they were born to a nutritional deficiency both of proteins and energy, showed it in the form of impair growth during the lactating period. As they switched from the monogastric to the poligastric stage, the nutritional deficiency dissapeared with an adequate supply of forages and concentrates and a recovery effect was apparent that would compensate for the retardation of growth in the previous stage. The recovery could be considered complete and the size and body weight perfectly normal, at approximately 6 months of age in the females and a little later in the males.

This recovery effect has been pointed out by various researchers, as a characteristic sequence of the deficiency period.

Waters established in 1908 that when an animal is undersize at a certain age because of a nutritional deficiency, it is probably capable when freely fed to compensate in part such loss with a greater improvement rate.

Although the signs of the recovery effect are generally known, the causes are not well established as yet. They have been attributed to a greater appetite, an increase of feed efficiency, and even simply to the increase of the filling material in the intestine. It is possible that all these factors play a part in this phenomenon.

We are of the opinion that a detailed study of the recovery effect is of the greatest economical importance so that it would allow to establish the most adequate levels of growth, according to the conveniences of each moment.

The maximum physiological rate of growth does not have to convene with the optimum economical level. The physiological variation of the animal as well as the cost of the nutrients can make advisable, temporary different levels.

For the particular case of our study, we can say that a low rate of growth during the stage of imperfect physiological rumination followed by a period of quick nutritional recovery, when the rumination is already perfectly established, results in a greater economical interest than the maintainance of a certain rate of growth right from the lactating period up.

Naturally this conclusion applies only to the prices that were prevalent in our study.

It can be objected that even when from an economical standpoint the periods of deficiency and nutritional recovery could be recommended, they are not if we consider the unfavorable permanent effects reported by the investigators of Cambridge.

We believe that in beef production there are two important genetic characteristics, independent between them, and perhaps to a certain extent an-

tagonistic, they are: the «precocity» of beef conformation and the «growth index». In our opinion the nutritional deficiencies in the young animal, affect more deeply the characteristics of beef conformation than the characteristics of growth. The alterations of this last one are, as a rule, easily corrected in the recovery period.

The Spanish bovine breeds, and in general those autochthonous of many other countries, subjected to broad climatic changes, are characterized by a deficient beef conformation and good growth index. The influence of the diet on beef conformation that can affect considerably the English breeds, is nevertheless much less important in these cases. Moreover, for young beef production, more common in Spain, it is of a greater economic importance to have a good growth index than a good beef conformation. On the other hand we have not been able to see in any of our experiments the reduction of feed efficiency apparently attributed by the English school to those animals improperly fed when they were young.

In older animals there exists an economical need to adapt the growth rate to the feeding possibilities, and this means in the practice, seasonable variations or waves of growth that in many regions are characteristic of beef production.

All this has not been well studied as yet. It seems probable that the duration and intensity of the periods of deficiency and recovery influence considerably the «recovery» effect and that there exists what it might be called «limit of nutritional elasticity», below which, recovery is not possible. Moreover, independently of this loss of the faculty of recovery, or of its considerable decrease there is another very important factor called loss of the condition or deterioration of the nutritional condition of the animal. As pointed out by E. J. Sheehy this is only simultaneous with loss of weight during certain periods but even with the maintenance of a variable weight. To avoid such loss of condition, it is necessary to maintain ratios of increase of the live weight that varies with the age and the weight of the animals.

In trying to obtain the rate of growth considered more adequate in each case, it is important to handle properly the interactions of the various types of feed available. Inadequate handling of this is in practice, one of the most evident causes of low production. We do not refer here to the classic distinction between concentrate and forages or bulk feed. Even among these last ones it is basic to be well acquainted with the complementary effects.

The famous table of Ingle, published by the Scottish Society of Agriculture at the beginning of last century, is a wonderful example of these studies. As far as we are concerned, it contains the fundamentals of all the English school of cattle feeding.

This complementary function of the various types of feeds is especially interesting when the economical factor suggests the formulation of rations based mainly in forages and coarse feeds that in general are the ones that contain the cheapest nutrients.

Frequently the energy requirements can be met with that type of feed as long as they are utilized at its maximum digestive capacity.

In our opinion, under these conditions the role of the concentrates is mainly to avoid the limiting effects that can be produced by the proteic and mineral deficiencies.

Although so far the studies concerning the utilization of the proteins by the ruminants are very incomplete, with great variations in the results of the



experiments, it seems generally admitted that proteins are frequently a limiting factor in the growth rate of cattle.

It is possible that this might be considerably influenced by the well known nutritional degradation of the pasture from springtime to summer. In some of the studies we have conducted in the Northwestern part of Spain, the area with the highest humidity of the peninsula, we could observe that a crude energetic efficiency of 14.5 % during the months of May and June was reduced down to 11.3 % in July and to 6.9 % in August.

In dryer areas the variation can be even of greater magnitude. This reduction in feed efficiency can affect the protein utilization.

Research work carried out at the Universities of California and Oklahoma have shown the practical usefulness of the protein concentrates when degradation of the nutritional value of the pasture, so characteristic of the dry areas, is produced.

We are of the opinion that in Spain the supplementary function of protein concentrates should be studied carefully.

Finally it is important to consider, as shown by Walker in his recent studies with cattle of North Rhodesia, that certain mineral deficiencies might exist, without being shown clinically, but by influencing the basal physiologic function and affecting the protein utilization would create suboptimum reasons for growth.

Salt is especially interesting at this respect, due to its recognized influence over the protein metabolism. It seems from the work of Sheehy and Richards that many old pastures are deficient in salt.

The possible existence of that inhibitory effect suggested by Walker as due to an excessive salt intake, advice the need for a more detailed experimental work on this subject.

It should be interesting to study in certain agricultural regions other mineral elements such as calcium and phosphorus that influence the basal physiologism.

## DISCUSSION

*Dr. Van Snick* (Belgium). Do you recommend a food with a high cellulose content for milk production giving the animal a good amount of food? It should be necessary to indicate if bovine cattle may be considered as monogastric at certain stages or periods.

*Dr. Quintanilla* (Spain). I think in some countries the animal is considered as monogastric rather than polygastric during the first months of its life. Regarding the tests mentioned in my report, we were especially interested in reducing feed consumption during the monogastric feeding period, which was exceedingly costly, and then recover this delay later on by feeding a higher amount of cheaper feeds.

*Dr. Stockstad* (U. S.). I would like to know whether there are any mineral deficiencies which interfere without producing any evidence of disease.

*Dr. Quintanilla* (Spain.) Even though we lack enough evidence, I believe it is probable that there are spanish pastures with the deficiency in salt which, as I said, have unfavorably affected the liveweight increase of bovine cattle in South Rhodesia. It is also probable that pastures deficient in phosphorous may produce an inhibitory effect similar to salt deficiency.

*Mr. Peruchon de Brochard* (France). I would like to make a comment



regarding feeding of bovine cattle with rations of low cellulose content. In France, where such animals are fed in dry lot with mixed feeds, we are using increasing amounts of concentrates (that is to say, mixes of cereals and cakes) of low cellulose contents, without having so far any accidents.

MODERATOR. No need for an answer is there? Thank you very much, Dr. Quintanilla, for bringing up such an interesting subject. I may say that getting the type of adult animal we want depends largely upon how the breeding has been managed. This is particularly important in bovine cattle, which after weaning change from a monogastric stage to a polygastric one, presenting physiological problems not yet solved. I also will insist on the fact that improved breeds are more sensible to feeding during their early life than rustic breeds.

Now, Dr. K. L. Robinson will talk about the subject «Milk Replacers».

## X MILK REPLACERS X

BY

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### *Introduction*

This paper deals with «milk replacers» for calves and baby pigs, and particularly with the role of fat in this connection. The nutrition of these very young animals has been the subject of much investigation — notably in the U. S. A. — the literature of which has recently been reviewed by Preston (1958); no general restatement will therefore be attempted.

The nutritional requirements of the calf and pig seem in some ways similar. Each has become adapted to depend during its early life upon a maternal milk of characteristic composition; each at the start is unable to digest carbohydrates other than lactose and glucose, but becomes able to deal with starch after a few weeks; each can digest proteins and fats, at least of the kind found in its native diet.

It is not surprising that in the earlier investigations, which relate mainly to calves, attempts were made to simulate natural milk by combining by-product separated milk with cheap vegetable or waste animal fat. Some of this work was carried out before the investigations of Blaxter and his associates had demonstrated the importance of vitamin E in the nutrition of the calf and before fat stabilization had become practicable, which probably accounts in part for the sometimes conflicting results obtained. Another feature should also be noted. Although it appears to have been generally appreciated that

fat added to liquid milk diets requires to be properly emulsified and homogenized, provision for adequate dispersion has frequently been lacking with diets fed dry, the fat being simply mixed into the solids. The results of the work of Hopkins, Warner & Loosli (1959), in which diets of this type were fed reconstituted with water, demonstrate the importance of an emulsifying agent in improving the digestibility of the fat. It seems a logical inference that this factor is of equal importance in dry-feeding.

There is at present a considerable interest in the addition of enzymes, both proteolytic and amylolytic, to cereal-based diets for young animals. If this work, still apparently very much in the experimental stage, should prove successful the benefits would inevitably be in the direction of low-cost rather than high intensity production. Although enzyme-treated feeds could probably have a useful application in the case of pigs a similar extension to calf feeding would seem less likely in view of the existing low-energy feeding systems based on the early development of rumen function.

### *Milk replacers for calves*

Loosli (1957) summed up the general position as follows: «A number of dry mixtures have been formulated which can replace fluid whole milk in the nutrition of calves starting at 3 to 10 days of age. Most products now available on the market are high in milk by-products. They usually do not allow as rapid gain in weight as whole milk, but the gain is fast enough to be satisfactory to most dairymen..... The problem with these dry feeds is that they are low in fat content and thus they furnish far less energy per pound than the solids of whole milk. Attempts to feed as much energy as calves obtain from whole milk usually cause scours from overfeeding. The problem of adding adequate fat to dry replacers for milk has not been solved.» Reviews by Roy (1958, 1959) bring out the same points. Studies by Raven and Robinson on the utilization of fat by calves have been in progress at Queen's University, Belfast, for several years. Some of our results are relevant to the present discussion.

Working with Ayrshire bull calves, it was established that the nitrogen retention from a skim milk diet is about 30 % of intake, as compared with 50-60 % for whole milk, and that the apparent digestibility of the fat in whole milk is about 97 %. The increase in efficiency of nitrogen retention was accompanied by greater efficiency in the retentions of Ca, Mg and P. It was therefore decided to use two criteria in evaluating fat supplements: (1) the apparent digestibility of the fat; (2) the ability of the fat to bring about a high efficiency of nitrogen retention, as compared with the ability of butterfat, each animal being generally used as its own control.

The test diets were prepared as homogenized and spray-dried filled-milk powders with a fat content similar to that of whole-milk powder. The fats mainly studied have been stabilized refined palm and palm-kernel oils, both hydrogenated and unhydrogenated, and a 2 : 1 mixture of the unhydrogenated oils; the melting points were in the range 27-39°C. (Raven & Robinson 1958, 1959, 1960). This work has enabled observations to be made on the effect of (a) mainly long-chain fatty acids (palm oil diet), (b) mainly short-chain fatty acids (palm-kernel oil) and (c) a range and proportion of fatty



acids similar to that of butterfat except for the absence of butyric acid (the 2 : 1 mixture).

The overall effect of the extra energy supplied by the vegetable fats has been to bring about a substantial improvement in the efficiency of nitrogen retention as compared with that on a separated-milk diet, the unhydrogenated fats being rather better than the hydrogenated. However the usual range of 40-50 % retention with the vegetable-fat diets is lower than that for whole milk. Similarly the digestibilities of the vegetable fats have averaged about 7 % lower than those of butterfat, with no appreciable difference between the various fats studied; there has been no indication that the chain length of the fatty acids was a significant factor with these calves. Although this lowering in digestibility is small, it has directed our attention to an effect on mineral metabolism which merits some consideration.

We have invariably found that undigested fat is largely hydrolysed, and apparently converted to Ca and Mg soaps. Consequently the excretion of substantial amounts of faecal lipid can seriously impair mineral retention. For all the vegetable-fat diets studied we have found the correlation between the daily faecal excretions of fatty acids and Ca (when the effect of N retention was kept constant) to be very highly significant ( $r = +0.837$ .  $P = 0.001$ .  $n = 10$ ). The same trend was also found with Mg, and these impaired retentions of Ca and Mg were accompanied by poorer retentions of P. The formation of faecal soaps also creates an analytical problem.

Ca and Mg soaps are not soluble in ether; a simple ether-extraction of the faeces results in an incomplete removal of the lipid material and therefore in an overestimate of fat digestibility. It is suggested that in order to obtain satisfactory figures for fat digestibility the method of analysis for faecal lipids should include an acid pre-treatment, before extraction, in order to convert the soaps into free fatty acids.

The striking effect of fat supplements on nitrogen retention, with milk diets, has led us to examine the effect of adding fat to meal mixtures for early-weaned calves (Raven & Robinson 1960b). The diets used are shown in Table I, the stabilized unrefined palm oil being melted and then thoroughly mixed into the other components of the dry meal mixture, but without any provision for emulsification. For calves weaned when 3-4 weeks old the digestibility of the added fat was only about 73 %. Nevertheless the increase in digestible energy due to the fat brought about a nitrogen retention of about 50 % compared with about 38 % for the basal diet. In a trial with somewhat older calves under similar conditions, a supplement of butterfat was about 82 % digested and raised the nitrogen retention from a level of about 26 % to one of nearly 40 %. It is clear from these experiments that the simple mixing of fat into meal, although substantially increasing protein utilization, did not secure as high a level of digestibility as was found with homogenized filled-milk diets. It has been shown in our studies with milk diets that an increase in the retention of nitrogen is generally accompanied by an increase in the retention of Ca, Mg and P. This increase in mineral retention may be limited by poor fat digestibility, and therefore the gain in weight to be expected from the improvement in nitrogen retention might not be realized. It would appear that the impaired fat digestibility with meal mixtures was due to inadequate dispersion. Therefore in a further series of trials the effect



has been studied of adding lecithin to milk diets and to meal diets. The figures for fat digestibility and nitrogen retention are shown in Table I.

TABLE I

| Ingredients (%)                                      | Diet A | Diet B |
|------------------------------------------------------|--------|--------|
| Spray-dried separated-milk powder                    | 20     | 20     |
| Maize meal                                           | 35     | 20     |
| Locust (carob) bean meal                             | 10     | 10     |
| Fine wheat offals                                    | 20     | 15     |
| White fishmeal                                       | 15     | 15     |
| Crude palm oil                                       | —      | 20     |
| Vitamins A, D <sub>3</sub> , E and chlortetracycline | +      | +      |
| Crude protein (%)                                    | 26.3   | 22.8   |
| Ether extract (%)                                    | 3.8    | 22.4   |
| Gross energy (kcal/g)                                | 4468   | 5398   |

The results indicate that when butterfat is simply mixed with separated-milk powder and fed reconstituted with water its digestibility by calves is markedly poorer than that expected for the butterfat of whole milk. They also show that the incorporation of lecithin can bring about a striking improvement, the digestibilities in two instances being similar to those previously found for the fat of whole milk. It is evident however that there are considerable differences between individual calves on each diet. In our experience this variability in fat digestibility between calves fed filled-milk diets is in contrast to their more uniform behaviour when on whole milk. Subsequently the same calves were given meal mixtures based on diet A (Table I), one of the diets including palm oil alone, and the other palm oil to which lecithin had been added. It is evident that lecithin again brought about a decided improvement in fat digestion, but as before there was some variation, only two calves — the same two as previously — achieving digestibilities similar to those for homogenized palm oil diets (Table II).

From the investigations so far described it can be concluded that: (1) for optimum fat digestion by young calves the fat should be efficiently homogenized; (2) the addition of lecithin to fat mixed with milk powder improves the digestion of the fat, but not consistently to the level attainable by homogenization; (3) the same trend is found when lecithin is added to fat in meal mixtures; (4) under equivalent conditions butterfat is more highly digested than any other fats tested, and has the greatest protein-sparing effect.

In a study of possible ways in which the nutritive value of vegetable fat might be raised to that of butterfat we have included supplements of safflower oil (80 % linoleic acid) and glyceryl tributyrates in milk diets where the fat was an hydrogenated palm-kernel oil. The amounts of supplements were those required to give the levels of linoleic acid and butyric acid present in whole milk. These additions were unable to improve either the digestibility or the protein-sparing effect of the palm-kernel oil by calves to the level for butterfat. Calloway & Kurtz (1956) similarly found that the simple replacement of hy-

TABLE II

|                                       | 1H        |           | 2H        |           | 3H        |           | Calf      |           | 4H        |           |
|---------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|                                       | Milk diet | Meal diet | Milk diet | Meal diet | Milk diet | Meal diet | Milk diet | Meal diet | Milk diet | Meal diet |
| Ether-extractable material digested % | 58.2      | 59.6      | 75.7      | 77.8      | 67.3      | 61.3      | 85.9      | 69.8      |           |           |
|                                       |           | 79.4      | 94.6      | 81.1      | 83.0      | 76.3      | 96.2      | 83.1      |           |           |
| Total energy digested (kcal/day)      | 2457      | 3837      | 2809      | 4487      | 2700      | 3957      | 2998      | 3973      |           |           |
|                                       |           | 2856      | 3113      | 4010      | 2928      | 3781      | 3158      | 4023      |           |           |
| Nitrogen retention (%)                | 11.6      | 25.8      | 44.1      | 48.8      | 44.5      | 37.1      | 51.0      | 41.4      |           |           |
|                                       |           | 28.2      | 51.2      | 46.1      | 45.2      | 42.3      | 63.6      | 47.1      |           |           |

The meal diet with no lecithin contained 20 % crude palm oil; the meal diet with lecithin contained 10 % crude palm oil. Both diets were based on diet A, Table I.

The milk diets contained 28 % butterfat, added by simple mixing to a separated-milk powder. For fats containing lecithin, this was included at the level of 3.3 %.

drogenated lard by tributyrin was without effect on the digestibility of the lard by rats. On the other hand the incorporation of butyric acid into the triglycerides of the lard, to the extent of one fatty acid equivalent, markedly improved its digestibility. This improvement in digestibility brought about by butyration seems particularly significant in the case of rats since the milk fat of these animals contains negligible amounts of butyric acid. It would seem possible that the beneficial effect of butyration may have a kinetic basis, by reason of the butyrated triglyceride being susceptible to a more rapid hydrolysis.

The question of the correct level of fat in milk replacers merits some attention. Blaxter (1950) has stated that for rapid gains in weight by calves on whole-milk diets, energy rather than protein is the limiting factor. Therefore it seems reasonable to assume that for any kind of milk replacer the ratio of total energy digested to protein digested should be as great as that for whole-milk. This presumes of course that the biological value of the protein is high. The optimum level of fat to be included will thus depend upon the level and digestibility of the protein in the diet. For additions of fat to separated-milk powder this optimum level would appear to be that present in dried whole milk. For meal mixtures of the type of diet A we have found that for simple admixture, without lecithin, an inclusion of 20 % palm oil is required to achieve the whole milk ratio. Any alteration in fat digestibility will clearly affect the level of fat required. This point is brought out in Table II, where it can be seen that the higher digestibility of the fat in a meal mixture containing 10 % fat with lecithin enabled this diet to have a digestible energy value comparable with that of a basically similar meal mixture containing 20 % of fat without lecithin.

#### *Milk replacers for baby pigs*

Although there are a number of fundamental similarities in the early nutrition of the calf and pig, the methods of rearing, on the farm, have less in common. Systems of calf-rearing requiring the use of milk replacers are in general use, whereas, in the case of pigs, artificial rearing and early weaning are only occasionally employed, at any rate in the United Kingdom. The wider application of a very large amount of fundamental work, reviewed by Lucas (1958) and by Manners & McCrea (1958), appears to have been limited by the difficulties of establishing satisfactory systems of management for indoor rearing. For this reason we have not as yet, at Queen's University, undertaken investigations with pigs comparable to those with calves and have concentrated more on developing a system of husbandry in which the pigs can be weaned when 2-3 weeks old, without the bane of repetitive outbreaks of scouring. Such a system, based on outdoor rearing in small insulated huts, has now been operated successfully and continuously for over two years (Coe, 1959). Preliminary observations with fattened-milk diets, using this system suggest that with pigs, as with calves, efficient fat supplementation of milk substitutes is likely to raise the plane of nutrition. That this is so has been convincingly demonstrated by the results of Cunningham & Brisson (1955) who studied the responses of very young pigs to supplements of lard emulsified in liquid-milk diets. Increasing levels of this well-digested fat brought about improvements in nitrogen retention. Another effect of the increased fat sup-



plement was to reduce the food intake of these ad libitum fed pigs. This effect, which appears to be a general one, could be of importance in relation to the incidence of digestive upsets. The shortcomings of diets containing the cheaper carbohydrates, starch and sucrose, in place of fat may be twofold. The diets themselves are of lower energy value than high-fat diets, and they are introduced at a time when the animal's ability to digest them is somewhat uncertain. This low level of available energy may lead to «eating for calories» and to over-feeding and digestive disturbances, intensified by the husbandry requirement of communal and ad libitum feeding. Our own observations (Coey & Robinson, 1957) suggest that pigs weaned at about 2-3 weeks old make the greatest growth during the succeeding 2 weeks when given diets based on whole milk powders, or filled milk powders containing vegetable fat, such as palm-kernel oil. The use of fatted diets appears to be of particular benefit in reducing the post-weaning check. After the fifth week or thereabouts the advantages of dietary fat are less apparent, conventional creep feeds based on separated milk powder, fish meal, maize meal and sucrose being satisfactory.

It has been frequently reported in the literature that young pigs fed conventional types of protein concentrate/cereal diets of high-energy content show no improvement in rate of growth when fat is incorporated by simple admixture. This has been our experience with pigs fed to appetite from 8 weeks of age, when using unrefined palm oil and refined animal grease at 10 % level. Under these conditions the digestibility of the fat was about 70 %, which would appreciably increase the digestible energy of the diet over that of the controls. The lack of response was therefore presumably because the pigs could obtain sufficient energy from the control diet for optimum growth by an increase in food intake, but without overfeeding. At the same time the possible effects of impaired mineral retention, brought about by the rather high excretions of faecal lipid, should not be overlooked. It would appear that with pigs, as with calves, the manner in which the fat is added to the diet is of paramount importance.

### *Some general considerations*

There would appear to be still some distance to travel before a solution to the milk replacer problem is reached. The formulation of substitutes containing fat seems to be the most promising field of investigation. Not only does dietary fat lessen the carbohydrate problem of the very young animal; it can have important effects on protein utilization. At the same time the simple incorporation of substantial amounts of fat into powders or meals, whether or not fortified by emulsifying agents, is likely to be limited in application partly on the grounds of variable digestibility but more particularly because of unsatisfactory physical condition due to oiliness. A possible alternative, one which we are currently investigating, is the use of milk powders in which the proportion of fat is much higher than in conventional filled-milks. But to make these worthwhile a really consistently high fat digestibility is required. Whether this will be brought about by interesterification of suitable fats or will be more simply achieved, remains to be seen.

Attention to the protein components of such dietaries may be less urgently required, but the recent investigations of Shillam, Dawson and Roy (1960) on

the effect of heat treatment of liquid milk suggest that this is a matter of considerable importance. In this connection it is tempting to speculate on the possibilities of «instant milks», with tailor-made fats, for animal feeding.

It is perhaps a matter of opinion whether or not much progress has been made, in practical application, from Loosli's assessment of 1957 and from the positions to which the advent of antibiotics had enabled us to advance at that time. On the other hand considerable advances have been made on fundamental aspects, and knowledge has become available which has made for a clearer understanding of the factors involved and which should lead to improvements in the nutrition of young animals on the farm.

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## DISCUSSION

MODERATOR. Thank you very much Dr. Robinson.

Dr. Varela (Spain). Dr. Robinson's paper has been very interesting for us, because it coincides with our own results. One problem we have in my country is to increase the maximum digestive tolerance for fats. In areas like the ones I mentioned this morning, olive growing areas, fat must, of necessity, be the source of energy. We are working along the lines of the TOWER School of the United States, using emulgents. These emulgents are not lecithin, but sulfocinate. The results we have obtained present a significative increase in fat digestibility, in tests performed on goats, pigs and



sheep. However, the use of lecithin seems to us a little premature, as we still lack the sufficient experience regarding incrustation or non-incrustation; for this reason we consider that sulfocinate type emulgents—which do not seem to have any incrustation action—might be more advisable.

*Dr. Breirem* (Norway). From Mr. Robinson's paper, we see that our studies in Norway are very similar to the ones carried out in Ireland, as it is an unquestionable fact that young calves can take fats without any detrimental effects. In some experiments performed with 10-week old calves we supplied first skimmed milk with vitamins A and B, then lard, coco fat and another type of fat; calves fed lard registered a satisfactory growth and we observed that estrocolesterol was very low in this case, while it was very high in calves fed coco fats. The third fat used showed intermediate values. However, we were not able to show a definite relation between lard and colesterol in metabolism. From this Irish research work we see that our results are rather interesting.

*Dr. Van Snick* (Belgium). I agree that the progresses made in fat incorporation are truly due to the solving of physico-chemical problems raised with the use of emulsifiers and fat stabilizers. However, I would also like to know the speaker's opinion with regard to the nature of fat substances and whether there have been any studies made about the superiority of vegetable over animal fats or whether there is any criteria which may justify the combined use of both. Another question: is there any definite data in support of the use of calcium and magnesium with respect to milk coagulation needs? As to the utilization of substances with starch content it seems that their use is constantly increasing, although with the addition of enzymes for improved assimilation. I wonder whether it should be necessary to examine the situation regarding starch suspension agents, in order to eliminate sedimentations?

*Dr. Robinson* (Ireland). All these questions are so interesting that we would need a lot of time to answer them in detail. Nevertheless, I will try to deal with them very briefly.

With respect to young calves, I think there is nothing against their being given, starting the third day a liquid with vegetable fat, in addition to the colostrum until three weeks (not a month) and then using farinaceous mixtures with water to prepare the animal for the weaning stage, although they also take it dry starting from the first month of age. Afterwards, and if we want a milk calf, the animal is fed an amount of good quality hay and some flour, or an amount of concentrates in order to increase nutrition and calories. As to the fats used, we employ palm oil and refined palm seed. However, one can resort to palm oil from West Africa, which is cheaper, mixes quite well and gives a good performance with cereals. We also have used crude palm oil, unrefined, adding it to the skimmed milk, emulsified and homogenized, at a 50 % proportion. All these products are quite satisfactory, but not as good as lard.

With respect to calcium and magnesium levels, there is no doubt that retention rate of magnesium is higher when a digestible fat is used in the diet, although we have still to make more detailed studies on the typical diets we have indicated. The same is true of calcium. There is a definite relation between these elements and nitrogen retention: one could have a diet low in energy, hay basis, and add calcium and magnesium in order to obtain a good retention. Anyway, these points are still somewhat obscure.



As regards starch, we are definitely opposed to feed it to calves. The best way to kill a calf is starch administered under any form, because calves are unable to endure it. In some cases the animal resists fermentation, but in other occasions starch kills the animal. Of course, all of this only applies to animals under three weeks of age, after which time the digestible systems change.

*Dr. Castella* (Spain). I am surprised to see that table n° 1 does not include mineral salts, while vitamins appear in a limited number. Is this due to the fact that vitamins and salts are considered now of less importance for artificial milks than before?

*Dr. Robinson* (Ireland). What we wanted to study was the effect of fat supplements, and this is the reason why we have not given too many details. The diet mentioned is an abbreviated formula; these formulas are published in the references quoted in our paper, and are readily available.

*Dr. Castella* (Spain). Another question, please. The main difficulty encountered with any artificial milk is due to lack of digestive capacity on the part of the calf or piglet. I would like to ask Dr. Robinson whether he thinks that it would be an interesting source of future research on the animal feed industry to solve this small digestive capacity by using the modern systems of enzymology and industrial microbiology which make it possible to pre-digest and hydrolize the ingredients used in these artificial milks. Such techniques are now a possibility for many feed manufacturing concerns.

*Dr. Robinson* (Ireland). In general terms, I think that would be quite interesting, and I hope we will be able to study this point in the near future.

*Dr. Ascarelli* (Israel). I would like to make just a little remark. In Israel, where carrots are produced in great quantities, we have observed that they have a toxic element. Therefore one should be careful when using them, although they do not have any detrimental effects on monogastric animals.

*Dr. Robinson* (Ireland). Carrot meal is quite common in the United Kingdom, and is included in all feeds for calves: however, their toxic element is not a strong one. Although we have already eliminated carrot meal from our ration, we are very grateful for your warning.

*Dr. Isler* (Spain). Experiments have also been made in Israel which seem to indicate an influence of liquid carrot extract on the rumen function, although we do not know how far these effects go.

MODERATOR. I would like to point out the importance of Dr. Robinson's paper and of the questions asked, in case there are no more questions.

I think that the milk replacers problem presents for all of us a more difficult question, digestibility, which deserved to be discussed from a physiological point of view, with more emphasis on the evolution of digestive secretions in young animals. In my opinion, there is no theoretical reason for not substituting entirely maternal milk for an artificial milk, although it still presents many difficulties from the practical point of view.

Now, I leave my place as Moderator to Dr. Cuenca, while I read my own paper (Dr. Simmonet reads his paper: «Feed Additives in the European Feeds»).

## ✓ FEED ADDITIVES

BY

DR. (SIMONNET)

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During the last years the addition of non-food materials to cattle feeds has become a general practice.

The main objectives of such a practice are the following: to simplify the preservation of some food components, and to introduce in animal feeding certain substances intended to stimulate a given type of production. When such is their ultimate purpose, we would describe such products as «auxiliary substances for nutrition».

The above mentioned practices have frequently resulted in heated controversies lacking the most elementary objectivity, and some breeders even advocate the return to the old methods of cattle breeding represented, for example, by the obsession of using hundred percent natural foods in cattle feeding, totally excluding other feedstuffs. The lack of consistency of such criteria is very obvious indeed.

Whatever the «a priori» opinion a particular breeder may have regarding this point of view, the use of additives has increased parallel to the scientific and technical development of our knowledge in breeding matters. However, the use of additives presents multifarious implications, which serve as a spur to improve our knowledge about the conditions under which such a practice is justified.

The use of additives, must meet three basic conditions, formulated during the Third Symposium of Foreign Substances in Foods, held in Como in 1957 (1).

1. The additive should under no circumstances have any detrimental effect on the nutritive, sanitary and/or technological qualities of the production.

2. The use of the additive must provide a real advantage or benefit for the intended production.

3. The amounts of the substance added, or amounts of conversion products to be found in the slaughtered animal or in products derived from the body

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(1) International Commission of Agricultural Industries, Paris, 1957.



of the animal, must be so balanced as to prevent any noxious effects in the person consuming such products.

The first condition does not call for any comments. The products added should not in any way impair the health of the animal. It may also happen that a useful practice for obtaining a given product impairs the health of the animal: «foie-gras», for example, may be considered as a pathological organ.

It may happen, too, that an additive proves detrimental with respect to a given type of production; such is the case with some anticoccids in relation with laying hens.

In any case, the organoleptic characteristics of the product used should not suffer any harmful variations. All too often, some breeders neglect this all-important point, which is of vital importance in poultry breeding. The enemies of this system use as a supporting argument the difference of quality — often disfavoured — observed between meat quality of poultry raised in battery and poultry fed «ad libitum».

The second «must» stands for a necessary condition. It is obvious that in animal husbandry the only profitable operation is a practical operation. For instance, it is a well known fact that iodinated proteins stimulate milk production; however, the estimations made show that the economic advantages derived from the increased milk production are barely offset by the augmented costs of iodinated protein administration.

This essential point of view — the operation must be justified on a profit wise basis — is a difficult one to determine. Even the most carefully accomplished experiments do not generally refer but to a specific type of operation. The advantages of the administration of a particular additive vary from one area to another, and between the different breeds. It should be taken into account that an improvement in the sanitary conditions of the environment, and the use of adequate rations may nullify the advantages provided by an additive, thus making its use superfluous; the breeder should also avoid becoming over-enthusiastic about any innovation, vogue or piece of advertising in the additive field without first weighing carefully all factors involved.

In any case, breeders' approval of a particular additive after several years of usage is the best proof as to the usefulness of such product.

Even more important, in our opinion, is the third condition, which determines in the last instance the introduction of nonfood substances in animal feedstuffs. Therefore, we will devote a particular attention to this important item.

The specific technique for preparation of the substance should be perfectly established, in the sense that the product used should be uniformly defined in all cases. This uniformity of composition should be easily tested on the basis of physical and chemical criteria, thoroughly determined. The product used should meet the highest practicable standards of purity. The nature of existing adulterations must be perfectly established and in no case should exceed the established ratio.

Before introducing a given product on the market, its biological effects should be carefully determined by applying the classical procedures of phar-



macodynamics (2), similar to those recommended for the preliminary study of a product or ingredient intended as an additive for human food.

- determination of lethal dose 50 (LD 50) as a measurement of acute toxicity.
- short term study of toxicity; the test was performed on a period of approximately two months, using a dose the determination of which still gives raise to controversies among the pharmacologists.
- long term study of toxicity on two generations of animals belonging to two different species, including investigation of a possible cancerous effect.

If the compound contains several products, the safety test shall be conducted not only on each of the separated products, but also on the whole mix, as they might have interaction effects; for instance, an increased improvement of intestinal reabsorption of one of the products may represent an increased toxicity in another.

Other tests should also be performed. The convenience of knowing the course followed by the product added to the food is quite obvious. The product often settles in some tissues and passes through the organism without any modification; however, it may also become separated into other elements whose physical, chemical or biological characteristics may not necessarily be the same as the initial product's.

It is necessary to determine both for the proportions used and for higher amounts the way in which the product is stored by the organism: quantity, and permanency of the product in a given organ or tissue. Summing up, it is necessary to know its metabolism and to estimate its course through the organism.

For this purpose, it is necessary to develop adequate means of identification and proportioning (physical, chemical and biological) of known nature, sensitivity and accuracy. Such proportioning methods should apply not only to the initial pure product, but also to the product or its by-products when incorporated to the different substances included in the extracts made from animal or vegetable tissues.

There are many «additives» which can be utilized in animal nutrition. Some of these products are only absorbed «by accident», i. e. they are involuntarily introduced in animal feedstuffs. Such is the case with residues of pesticides, insecticides, fungicides, rat killers, defoliation agents, weed killers, germination inhibitors, etc., and substances from packing materials or handling equipment, to say nothing of labelling errors in the mixes or involuntary substitutions.

The «real» additives, which are voluntarily introduced in animal foods can be classified into four groups, namely:

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(2) See, among others: Records of Examination of Authorized Products, Gazette Officielle de la Republique Francaise, 16 de Oct. 1958. V International Congress on Nutrition, Washington, D. C.; Effects of Processing and Additives on Foods, B. L. OSER; Modern Technology and its Relationship to Food Proficiency, V. Panel.

1. Substances — generally nutritive ones — whose application has been established by common usage: aromatic seasonings, minerals, sugary products, aminoacids and vitamins, its use being limited by its effects on the health of the animal rather than by the hygienic quality of their production.
2. Substances employed in order to improve the overall technological quality of animal feeds, such as antioxidating agents, separators, enzyme inhibitors, emulsion stabilizers, bacterial inhibitors and mould inhibitors.
3. Substances used for improving zootechnic production: growth stimulants, antibiotics, growth inhibitors, antithyroid agents, metabolism modifiers, estrogens, arsenics, antimony, modifiers of the nervous system, sedatives and tranquilizers.
4. Products used for preventing the development of parasites in the animal: coccidiostatics, vermifuges and microbicides. These products present the problem of delimiting their use with respect to veterinary and medicinal products proper.

All these substances have been praised and used to different degrees by all European countries, and are subjected to official regulations, which show a very unfortunate disparity. The anachronism of such disparities has become all the more acute with the establishment of the European Common Market, because of the natural trend towards increasing trade exchanges between countries of rather limited extension, whose productions are often competitive. For this reason it would be highly desirable that the agreements established between members of the European Common Market, and between such members and other countries not belonging to this organization be revised in order to introduce more uniform criteria in the future, which will be of great help whenever a new product is considered for use as an additive.

It is not our intention to go too deeply into this side of the additive problem; however we will report several examples in support of our point of view.

At present, all European countries have planned to establish a suitable legislation which would include, in addition to the required definitions and characteristics relating to both simple and mixed foods, some regulations applicable to additive products, setting up control produces and penalties.

In general lines, lists of additives are prepared under two different points of view. They may take the form of «positive» lists, i. e., a list enumerating those products whose use is authorized provided certain proportioning conditions and methods of usage are observed: duration, animal species, type of production, etc.

There are also the so-called «negative» lists which include all substances the use of which is forbidden, in addition to the particularities of such prohibition in each case, including sometimes regulations of general nature, such as those established in Great Britain:

«Any person or persons who sell, offer for sell or promote the use as animal food of any product or products containing noxious substances for animal consumption will be held guilty of infraction».

The substances enumerated under paragraph 1 (page 7) — Substances of



common usage in animal nutrition—are generally subjected to special regulations: such is the case of «axerofol», for example, whose proportioning and stability are a matter of justifiable concern for the authorities.

With respect to additives proper, auxiliary substances for nutrition or special active principles, the differences of opinion are much more pronounced.

The use of antibiotics is also equally established as regards type, minimum ratios and, in some cases, maximum ratios, too.

Some products are specifically prohibited by law in some countries. Such is the case of the estrogens, which are forbidden—at least—in France, Switzerland, Denmark, and West Germany.

Belgian regulations still show some doubts as to the difficulty or rather the impossibility—of demonstrating that such products have not been used in animal nutrition.

In other countries, Italy for example, regulations to this effect are still unknown.

France has regulated the use of antioxygenes (most other countries have not yet done anything in this direction). The status of arsenical products still varies according to the different countries; they are specifically prohibited in France, practically prohibited in Belgium and implicitly forbidden in Denmark, while they are authorized in Holland.

Tranquilizers do not seem to have received any legal attention.

Antithyroids constitute a typical case of controversy; while they are considered illegal in France and West Germany, in Holland their use is allowed, provided a special license is secured.

Anticoccids legislation is rather complex; on the other hand it deserves special consideration, inasmuch as these substances are widely used with therapeutic purposes; its incorporation to animal feeds having, essentially, a preventive purpose.

Summing up, and notwithstanding the general trend towards increasing regulations, such regulations will not become useful in international trading until the following points are established by mutual agreement:

- 1) Definition of additives.
- 2) A list of substances the use of which is rigorously prohibited, without any exception whatsoever.
- 3) A list of authorized products, establishing the conditions which regulate their use.
- 4) Methods of dosage and proportioning of authorized products.
- 5) Provision of agreements for joint studies of any new products which may be considered for use as feed additives.

## DISCUSSION

*Dr. Cuenca* (Spain), *acting as Moderator*. We have just listened to a wonderful summary of Prof. Simmonet, which reveals his wide experience in the subject discussed. Now we will open the discussion, starting with a question asked by Dr. Castella.

*Dr. Castella* (Spain). I considered that the subject treated is so interesting for the future of the feed manufacturing industry that I would like to express my personal opinion on the subject. If we review the history of animal



husbandry we will see that the Zootechnic Pharmacology, i. e., the application of production stimulants for animal nutrition, was born after the end of the Second World War and was developed immediately by the United States which, by not being binded by any traditional prejudices commonly existant in Europe, did not have to fight against the existing criteria regarding the dangers of intoxication. Traditionally, there has also been a great fear of toxicity regarding the use of medical products. However, if the danger of intoxication is a pressing problem, the world has now another problem, famine created by the defect of protein production, which is far more important. For this reasons, I would like to say that the most reasonable position might be to carry out all our activities for increasing production as long as we did not encounter any definite proof of danger with a given product. This is the case, for instance, of arsenic, forbidden by legislation in many countries. If arsenic cannot produce cronic intoxication in poultz or pigs, during their whole economic span of life, what possibilities there exist of arsenical residues in the carcass producing detrimental effects in human consumption, if we already know that the levels supplied are favorable as long intoxication limits are not reached? This is my personal position, and I am grateful for the opportunity for expressing my opinion.

*Dr. Simmonet* (France). Your position is a very interesting one, and your summary of the problem has been very well developed. However this is a question of hard facts. First of all, we must know whether additives are indispensable to produce the necessary amounts of food for solving the problems created by food shortages. Second, it is necessary to determine whether the product used can be detrimental for human consumption. I am neither in favour nor against arsenic utilization, but I ask that the people responsible for this type of legislation in all countries get together in order to come up with some homogeneous legislation. I believe we all agree on this point.

*Dr. Knut Breirem* (Norway).

MODERATOR. Thank you very much, Dr. Breirem. Now, Dr. Herbert Luther will talk about «Potentiation of Antibiotic Action».

## POTENTIATION OF ANTIBIOTIC ACTION

BY

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The quantification of the effect of the various factors influencing the utilization of antibiotics has recently been an area of intensive and profitable investigation. This has aided in the clarification of mechanism of action of antibiotics and, therefore, allowed for more efficient use of some of the antibiotics. This has stimulated the evaluation of certain agricultural applications of antibiotics under potentiated conditions, such as disease control, in areas where heretofore their use may have been impractical due to cost considerations (1) (2). It has even opened the investigation, on an economically feasible basis, of possibly increasing the keeping quality of poultry and live-stock by short time high level feeding of antibiotics under potentiated con-

ditions (3). There are several reviews on potentiation of antibiotics for agricultural uses (4) (5) (6).

The use of low levels of antibiotics for growth of poultry and livestock is widely practiced for over ten years, and literature references date as far back as 1946 (7). In recent years, however, the use of antibiotics for treatment and prevention of animal diseases has become an accepted commercial practice, and a symposium has been held on Medicated Feeds (8).

This large scale increase in the commercial use of high levels of antibiotics focuses attention on the economics of such practices, for in medicated feeds, antibiotic levels of 100 or 200 grams per ton are common instead of the levels of 2 to 10 grams which are used for growth promotion.

The cost of antibiotic treatment under these conditions becomes an important and possibly governing factor, and, therefore, considerably more attention is focused on the level of treatment required, which directly involves biological availability. At the present time, broad-spectrum antibiotics are widely used in the poultry industry for the treatment of such diseases as blue comb, chronic respiratory disease, synovitis, hexamitiasis, sinusitis, early chick and poult mortality. In swine, antibiotics are widely used for scours, enteric disorders, leptospirosis, vibrio dysentery, necro, salmonella infections, bloody dysentery, bacillary infections associated with virus diseases, as an aid in atrophic rhinitis, etc., and in cattle for bacterial diarrhea, as an aid in reduction of incidence of shipping fever, bloat, etc.

There are also many other disease conditions for which antibiotics are helpful, however, the level required for treatment is higher than that which is economically feasible. A typical example is the recent work with fowl cholera (2). In this particular study oxytetracycline (OTC), for example, was effective at levels of 1000 grams per ton in the ration. Comparable observations have been obtained with the use of the broad-spectrum antibiotics in the treatment of coccidiosis in chickens, however, levels in the order of 600 grams per ton are required for control of the disorder in normal rations, and these are not commercially feasible, especially when compared with the other coccidiostats which are available for the treatment of this condition. The use of antibiotics in many diseases of animals is such that the cost of medication is appreciable and in certain instances, the level of antibiotic administered is often influenced or governed by economic considerations, rather than by considerations of maximum efficacy. In view of the economics surrounding commercial antibiotic medication through feed, it is natural that attention has been focused on factors influencing the efficacy utilization of antibiotics.

### *Antibiotic Inhibition*

As early as 1951 work was reported relating to the fact that the broad-spectrum antibiotics, Terramycin\* and Aureomycin\*\* complex with various metallic cations (9). The reactivity and stability constants for the metallic

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\* Terramycin is the Trademark of Chas. Pfizer & Co., Inc. Oxytetracycline (OTC).

\*\* Aureomycin is the Trademark of Lederle for Chlorotetracycline (CTC).



complexes of OTC and CTC with ferrous and ferric ions, cobalt, zinc, manganese have been published (10), and are shown to be practically identical for both antibiotics. The colored complexes which these antibiotics form with metallic ions have been used as a basis for chemical determination of antibiotics (9). Ferrous and ferric form red complexes, copper and nickel form green, and others form yellow compounds.

Certain acids, including citric, tartaric, phosphoric and their salts as well as other acids have been shown to be effective in increasing the oral adsorption of broad-spectrum antibiotics (11). Aluminum also has been reported to reduce the adsorption of broad-spectrum antibiotics (12) (13) (14). Antacids other than aluminum do not show this inhibiting effect on adsorption of antibiotics (15) (16) (17) (18).

In the human field, the inhibitory action of certain multivalent ions, including calcium, has shown with the tetracycline antibiotics (19) (20). Dicalcium phosphate, as a component in oral administration, has been shown to result in a reduction of antibiotic activity in studies with rats and humans (21) (22). The effect of sodium meta-phosphate in enhancing antibiotic adsorption has been attributed to its ability to bind the inhibitor, calcium (27). Phosphates apparently depend for their enhancing effect, upon the presence of the inhibitor, calcium (24) (25).

There have been many procedures employed for determination of potentiation of antibiotics. The main method involves the determination of the equilibrium antibiotic blood serum level. Various dosage methods are employed including continuous feeding, «slug» feeding, and special dosing methods, such as the duodenal loop method (26). Naturally, the relative liver and other tissue antibiotic levels are another possible measure of potentiation, and various dosage methods have been employed using tissue levels as a criteria. Urine antibiotic levels have also been used to measure antibiotic potentiation, and have been of special value in measuring the method of potentiation involved with the use of terephthalic acid (TPA) as a potentiator.

The use of bacteriological techniques have been helpful in obtaining basic data on potentiation. These involve determination of the relative minimum inhibitory concentration (MIC) of antibiotic in suppressing the growth of an organism when maintained in broths containing various additives (27). Reversal of antibiotic inhibition following exposure of antibiotic to specific inhibitors is a technique which also yields information on potentiation.

The comparative and preferential antibiotic and calcium uptake by washed cells is a technique that yields some basic information in this area (28).

One of the most practical methods of demonstrating antibiotic potentiation is the area of disease control trials. Many disease conditions including C. R. D., Synovitis, Coccidiosis, Fowl Cholera have been employed to demonstrate increased antibiotic utilization by administration under favorable conditions yielding antibiotic potentiation.

Recently the keeping time of poultry has been employed to demonstrate increased adsorption of antibiotic by adjusting the composition of the diet, both as to the level of calcium fed, and the presence of terephthalic acid as a potentiator (3). Naturally, slightly increased keeping time of the meat was the result of increased antibiotic blood levels and, therefore, increased antibiotic tissue levels, when the antibiotic was fed under conditions more favorable to a higher antibiotic adsorption.



From a laboratory, standpoint one of our earliest practical agricultural encounters with antibiotic potentiation, or rather antibiotic inhibition, was in field work with mastitis. We had been receiving field reports of cases where antibiotics were claimed to be ineffective in treating the disease.

Determination of the sensitivity of the cultures obtained from these cases showed Terramycin in every case to be effective against the organisms involved when the tests were run by the standard laboratory procedures employing nutrient broth. In an attempt to determine why the laboratory experience differed from the field reports, we studied the effect of various milk constituents when added to the culture media, to determine what the actual action of the antibiotic might be when added directly to the udder. In studying this problem we found by adding fourteen different constituents of milk, that magnesium phosphate, magnesium chloride, calcium chloride, milk ash, and calcium caseinate exhibited inhibitory action against the antibiotic (27).

A five to ten-fold antibiotic inhibition was shown by some milk constituents and significant inhibitions obtained in the case of OTC, CTC, Dihydrostreptomycin, Polymyxin and Neomycin; however, the actual degree of inhibition varied somewhat with each antibiotic. Sodium Citrate was the only milk constituent that significantly enhanced antibiotic action.

#### *Relative Inhibition of Different Antibiotics*

The relative inhibiting effect of calcium on different antibiotics is of considerable importance. The comparative inhibiting effect is shown in the semilog plot (Fig. I). The data were obtained by bacteriological techniques employing micrococcus pyogenes, various aureus strains, Ps. aeruginosa strain 1014.

Penicillin is essentially uninhibited by practically any level of calcium employed in the study, and Chloramphenicol is only slightly inhibited by increased levels of calcium. Terramycin, Oleandomycin and Aureomycin are inhibited to a greater degree, with Dihydrostreptomycin and Neomycin showing the greatest reduction of activity. There is evidently a relationship between the susceptibility of antibiotics to inhibition by cations and their calcium-complexing ability. Neomycin and Polymyxin, which are subject to maximum inhibition have very high calcium complexing potential, whereas antibiotics which are not as susceptible to divalent cation inhibition, show a lower calcium-complexing ability.

It is possible to reverse this inhibition by adding calcium complexing substances, such as chelating agents, and by certain acids and salts (27) (28) (29). Figure II shows the effect of sodium citrate, potassium oxalate and ethylenediamine tetra-acetic acid (EDTA) on reversing the calcium binding effect on Terramycin. It is quite obvious that low levels of these materials are effective in reversing the calcium inhibition. These data in Figure II were obtained using bacteriological techniques. Similar observations have been obtained using *in vivo* studies employing the duodenal loop procedure (26).

The quantities of different antibiotics and chelating agents required to compensate for the inhibition induced by the addition of 0.2 % molar-calcium have been determined (26), establishing that the minimum molecular ration of calcium to antibiotic that was effective in inhibiting Terramycin *in vitro* (50 : 1) was also capable of suppressing *in vivo* absorption of Terramycin.

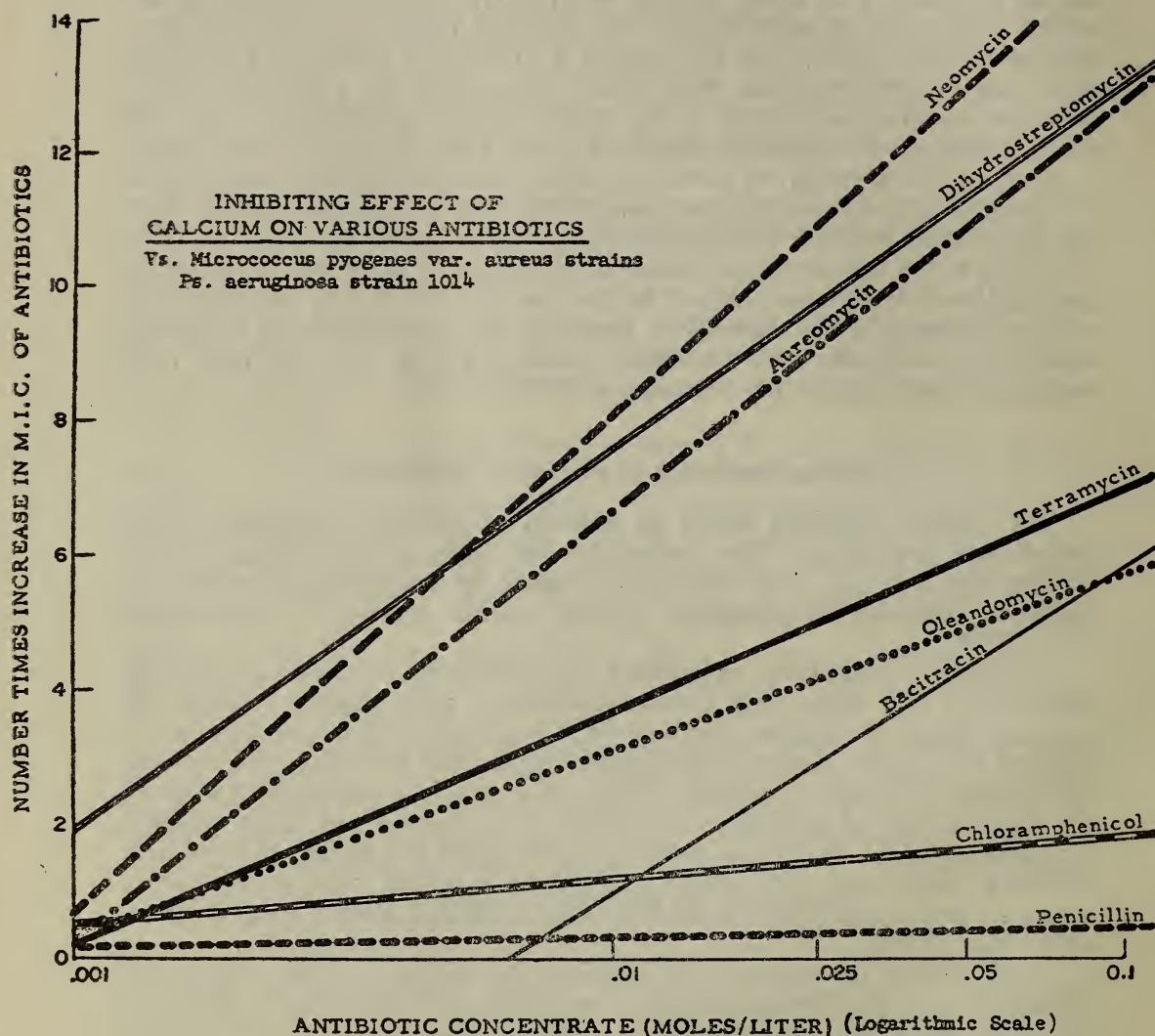


Fig. I



Citric acid and sodium metaphosphate have been found capable of increasing antibiotic absorption only in those cases where the tetracycline has been inhibited by the presence of a cation.

In our laboratories employing different feeding procedures, we found a difference in action of potentiator depending upon the method of feeding. For example, citric acid was required to be fed at fairly high «slug» doses before consistent enhancement was obtained, as continuous feeding of low levels of citric acid gave no enhancing effect. TPA on the other hand elicits a consistent response when fed continuously at low levels.

It has been shown that other cations have an inhibiting action. Comparative data is shown in Figure III. In this study with chickens, it can be observed that ferric iron and aluminum gave greater inhibition than other cations. In commercial practice, the inhibiting effect of calcium is of greatest concern in view of the high levels of calcium normally present in the rations of animals, particularly chickens.

Several other compounds have been evaluated by the duodenal loop procedure on the study of citric acid and kojic acid, and this information is given in Table I. These particular acids were selected as citric acid would be expected to have some activity in tying up calcium due to the relative insolubility of calcium citrate. Laboratory data indicates kojic acid might be expected to tie up calcium and certain other ions by its chelating action.

TABLE I

EFFECT OF CITRIC ACID AND KOJIC ACID ON ABSORPTION OF OXYTETRACYCLINE FROM THE DUODENAL LOOP IN THE PRESENCE AND ABSENCE OF EXOGENOUS CALCIUM (4 mM)

| Acid Added (mM) |       | OTC   | OTC+ACID | OTC+Ca | OT+CACID+Ca |
|-----------------|-------|-------|----------|--------|-------------|
| <i>Citric</i>   |       |       |          |        |             |
| 0.4             | Serum | 6.67  | 0.71     | 0.40*  | 0.53*       |
|                 | Liver | 1.06  | 1.39     | 0.88   | 1.04        |
|                 | Urine | 68.10 | 75.80    | 36.30* | 62.40**     |
| 0.8             | Serum | 0.54  | 0.56     | 0.37*  | 0.55**      |
|                 | Liver | 1.47  | 1.35     | 1.14   | 1.45        |
|                 | Urine | 81.00 | 68.00    | 26.80  | 71.00**     |
| <i>Kojic</i>    |       |       |          |        |             |
| 0.8             | Serum | 0.54  | 0.58     | 0.32   | 0.27*       |
|                 | Liver | 1.32  | 1.30     | 0.74*  | 0.81*       |
|                 | Urine | 75.60 | 65.30    | 25.20* | 21.90*      |

\* Significant decrease from OTC (oxytetracycline).

\*\* Significant increase over OTC + Ca.

OTC — Oxytetracycline.

From Table I it can be seen that citric acid addition, under normal calcium conditions, had rather limited effectiveness when added at molar concentrations of 0.4 or 0.8 mM. This is essentially the case, whether the criterion be serum level, liver level, or urine level. It is to be noticed, however, that the addition of calcium showed this divalent ion to be an inhibitor as measured by its



effect on serum, liver and urine levels. In the presence of calcium, however, the addition of citric acid at a 0.4 mM. concentration, partially neutralizes the deleterious effect of calcium. When citric acid is added at 0.8 mM. concentration, it completely counteracts the deleterious effect of calcium. This indicates that citric acid, as measured in this test, would be a desirable potentiator when divalent ions were acting as inhibitors. In practical feeding tests, however, citric acid has shown little potentiation unless given in «slug» doses. Kojic acid, on the other hand, when added at 0.8 mM. had no apparent effect on potentiation of OTC under either normal or high calcium conditions.

### *Terephthalic Acid*

TPA was of particular interest as it exhibits a different mode of action which can be clearly illustrated by the information in Table II, which summarizes the effect of TPA in the presence and absence of added calcium. It can be clearly seen from the information in Table II, the addition of terephthalic acid materially increases the antibiotic blood level, liver level and significantly reduces the antibiotic level in the urine. The addition of TPA at both the 0.4 mM., and 0.8 mM., reverses the interfering effect of calcium. This is of especial significance in that the advantage of TPA addition can be demonstrated both in the absence and in the presence of the inhibitor calcium.

TABLE II

EFFECT OF TEREPHTHALIC ACID ON ABSORPTION OF OXYTETRACYCLINE FROM THE DUODENAL LOOP IN THE PRESENCE AND ABSENCE OF EXOGENOUS CALCIUM 0.4 mM.

| Terephthalic<br>Acid Conc., mM |       | OTC   | OTC+Acid | OTC+Ca | OTC+Ca+Acid |
|--------------------------------|-------|-------|----------|--------|-------------|
| 0.4                            | Serum | 0.54  | 0.81**   | 0.28*  | 0.36        |
|                                | Liver | 1.12  | 1.64**   | 0.85*  | 1.02        |
|                                | Urine | 87.20 | 50.00*   | 26.70* | 21.50*      |
| 0.8                            | Serum | 0.70  | 1.03*    | 0.27*  | 0.53***     |
|                                | Liver | 1.10  | 1.42*    | 0.80*  | 0.93        |
|                                | Urine | 81.80 | 58.90    | 42.40* | 31.50*      |

\* Significant decrease from OTC (oxytetracycline).

\*\* Significant increase over OTC.

\*\*\* Significant increase over OTC + Ca.

The antibiotic urine level is of special significance when terephthalic acid is added. This apparent effect of TPA in governing the threshold level of urinary secretion of the antibiotic, indicating a different mode of action from that of other materials, several of which bind the interfering cation by chelation or forming insoluble complexes.

*Additive Effect — Potentiators*

As TPA evidently operates through decreasing urinary secretion of antibiotics, it was of interest to determine if the effect of TPA might be additive to the effect of those materials which operate by binding the interfering calcium. Data on this point is given in Table III. In this particular case, it is noted that the TPA and glucosamine are studied separately, and in combination.

An improvement in adsorption results from TPA addition, even in the absence of added calcium, in this case showing an increase in blood levels by 34 % and 23 %, respectively. Glucosamine additions in the absence of high calcium increase the blood levels by 11.6 %. The effect of glucosamine in the presence of high calcium is in sharp contrast, showing increased response of 44 and 30 %, suggesting that glucosamine has its action mainly in the presence of the inhibitor, calcium. When TPA and glucosamine are added together, TPA has 54 % and 39 % improvement in the presence of calcium, and increases the potentiation by 39 % over the 44 % which had already been obtained by glucosamine alone in the presence of calcium.

TABLE III

EFFECT TPA GLUCOSAMINE W/VO CALCIUM  
(Duod. Loop Method)

|               | N O R M A L     |          |          | C A L C I U M   |          |          |         |
|---------------|-----------------|----------|----------|-----------------|----------|----------|---------|
|               | 0/0 Improvement |          |          | 0/0 Improvement |          |          |         |
|               | X TM            | From TPA | From GLU | X TM            | From TPA | From GLU | From CA |
| S TM (.41γ)   |                 |          |          | .054            |          |          | —46     |
| E + TPA       | 1.34            | 34       |          | .083            | 54       |          | —38     |
| R + GLU       | 1.11            |          | 11       | .078            |          | 44       | —32     |
| U + TPA & GLU | 1.41            | 23       | 6        | 1.08            | 39       | 30       | —24     |
| M             |                 |          |          |                 |          |          |         |
| L TM (.95γ)   |                 |          |          | .65             |          |          | —35     |
| I + TPA       | 1.39            | 39       |          | .82             | 26       |          | —41     |
| V + GLU       | 1.24            |          | 24       | .87             |          | 33       | —30     |
| E + TPA & GLU | 1.31            | 6        | 6        | 1.79            | 118      | 104      | —37     |
| R             |                 |          |          |                 |          |          |         |
| U TM (120.γ)  |                 |          |          | .46             |          |          | —54     |
| R + TPA       | .54             | 46       |          | .19             | 61       |          | —250    |
| I + GLU       | .94             |          | 6        | .64             |          | —39      | —32     |
| N + TPA & GLU | .52             | 45       | 4        | .48             | 35       | —150     | —8      |
| E             |                 |          |          |                 |          |          |         |

E X TM = times the normal Terramycin level (γ/mg.).

TM ( ) = tissue level γ/mg. of Terramycin in unpotentiated control Terramycin group.



Antibiotic liver levels, when used as a measure of potentiation, give the same picture. Glucosamine essentially shows no effect under normal conditions, however, it supports approximately 65 % improvement in the presence of high calcium. TPA again supported additional improvement when added in the presence of glucosamine. Glucosamine increased urine levels in contrast to TPA, which decreased urinary excretion. In cross-over studies with dogs (30), glucosamine significantly enhanced tetracycline; serum levels supporting a 76 % increase in blood levels at 1 hour, and a 34 % improvement at 3, 5, and 7 hours.

Radioactive studies have also been conducted with glucosamine and OTC with both dogs and mice. A twofold increase in the blood level resulting from a 1 : 1 glucosamine addition (31). Several other studies have been conducted in humans evaluating the potentiating effects of glucosamine (32) (33) (34) (35).

### *Comparative Data on Antibiotic Potentiation*

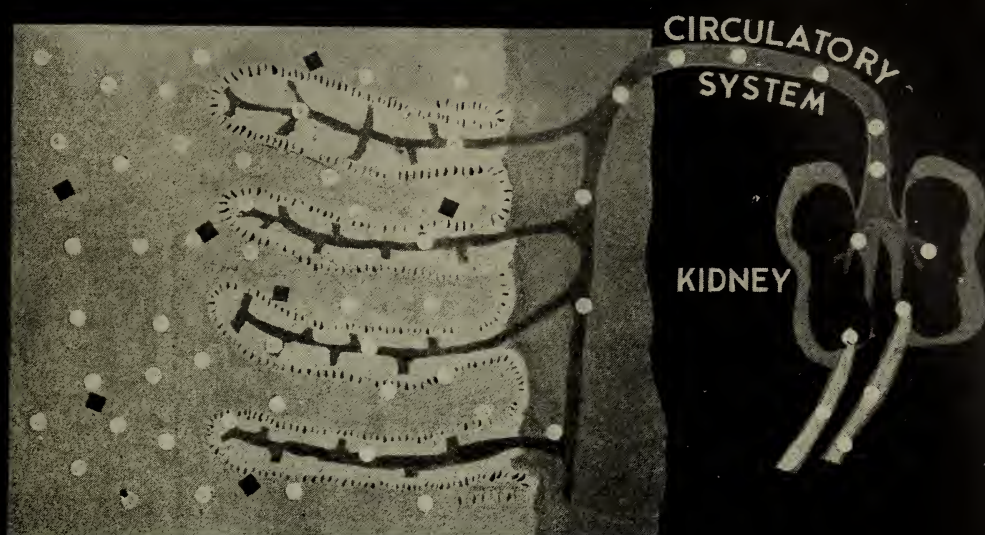
Naturally the calcium level and the calcium-phosphorus ratio of the diet will materially influence adsorption of antibiotic. Table IV gives information on the resulting blood levels from graded levels of antibiotic addition at various calcium levels, various calcium-phosphorus ratios, both with and without the addition of TPA. This information is tabulated for both Terramycin and Aureomycin, and represents the results from a very large number of feeding trials in our laboratories. These two broad-spectrum antibiotics are those which are mainly used for the treatment and prevention of animal diseases in commercial practice.

The data presented in Table IV has been arranged so that the effect of each variable has been isolated and can be assessed independently. Antibiotic levels in the feed from 100 to 1000 grams per ton have been employed. The diets included low (0.18 %), normal (1.2 %), and high level (2.25 %) calcium. Normal (0.7 %) and high (4.87 %) phosphorus levels were also employed. In almost all trials an overlay of 0.35 % of TPA was included.

Considerable commercial and academic attention has been focused recently on the degree of potentiation obtained with different antibiotics through the use of TPA, by reduction of calcium, and by the combination of these enhancing techniques. A study of the results in Table IV should serve to clarify these issues. The data in Table IV clearly shows the interaction of all the factors studied. When treating diseases systemically, potentiation basically becomes an economic study, for one is attempting to maximize antibiotic blood level at a minimum cost. The data in Table IV gives both the actual magnitude of increase in antibiotic serum level in  $\gamma$ /ml. as well as the percentage increase.

From the standpoint of minimum cost, one must naturally compare the cost of using increased levels of antibiotic with the use of potentiation like TPA, and also by dietary calcium reduction. Naturally calcium reduction is the least cost approach; however there are other nutritional considerations involved when this method is employed.

From the data in Table IV, which is also shown graphically in Fig. IV & V, it can be seen that both Aureomycin and Terramycin show a consistent increase in blood level with increased antibiotic level, the presence of TPA reduced calcium, and increased phosphorus level. The absolute response to



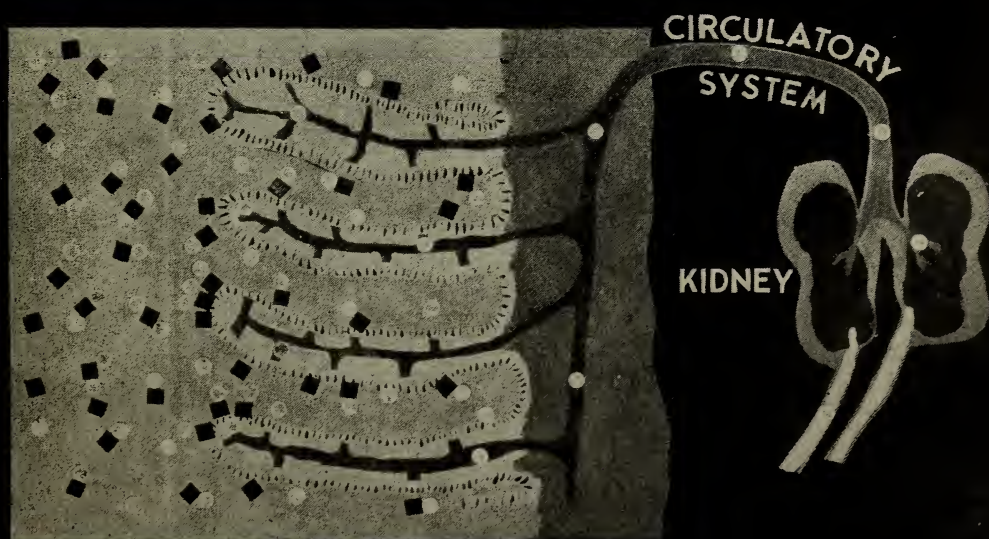
INTESTINAL SEGMENT

CIRCULATORY  
SYSTEM

KIDNEY

LOW  $Ca$  CONTROL

*Fig. VI*



INTESTINAL SEGMENT

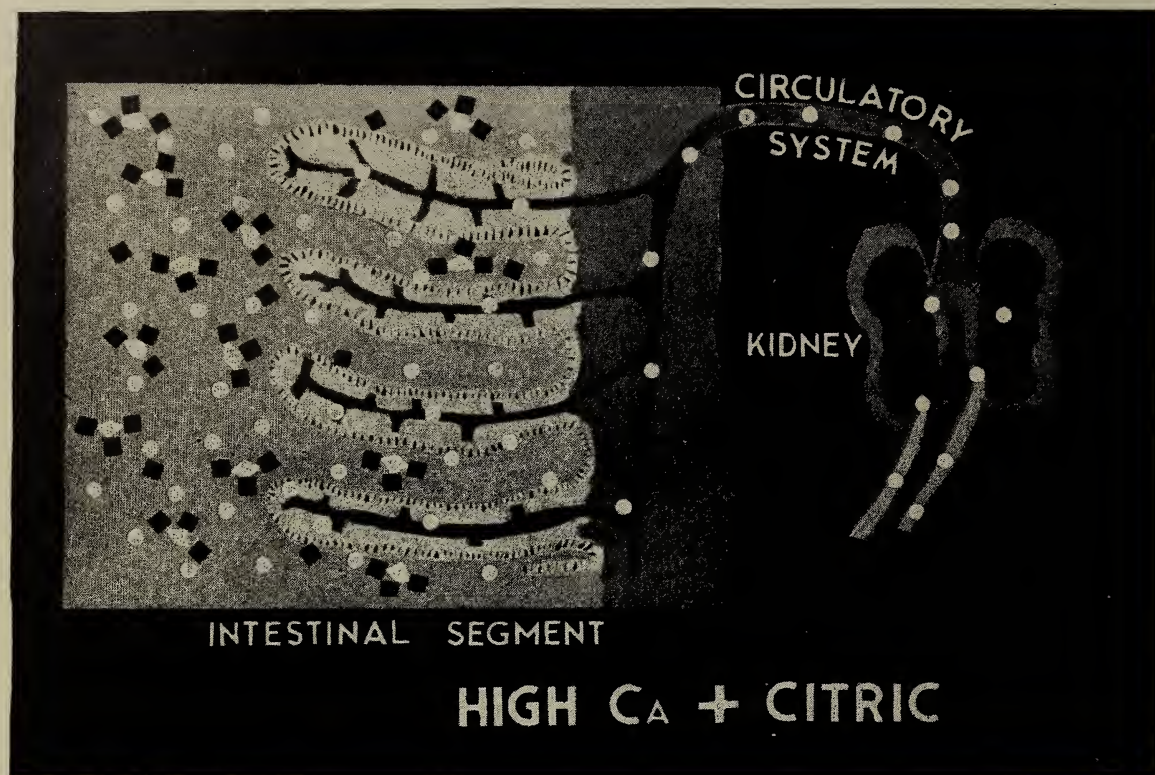
CIRCULATORY  
SYSTEM

KIDNEY

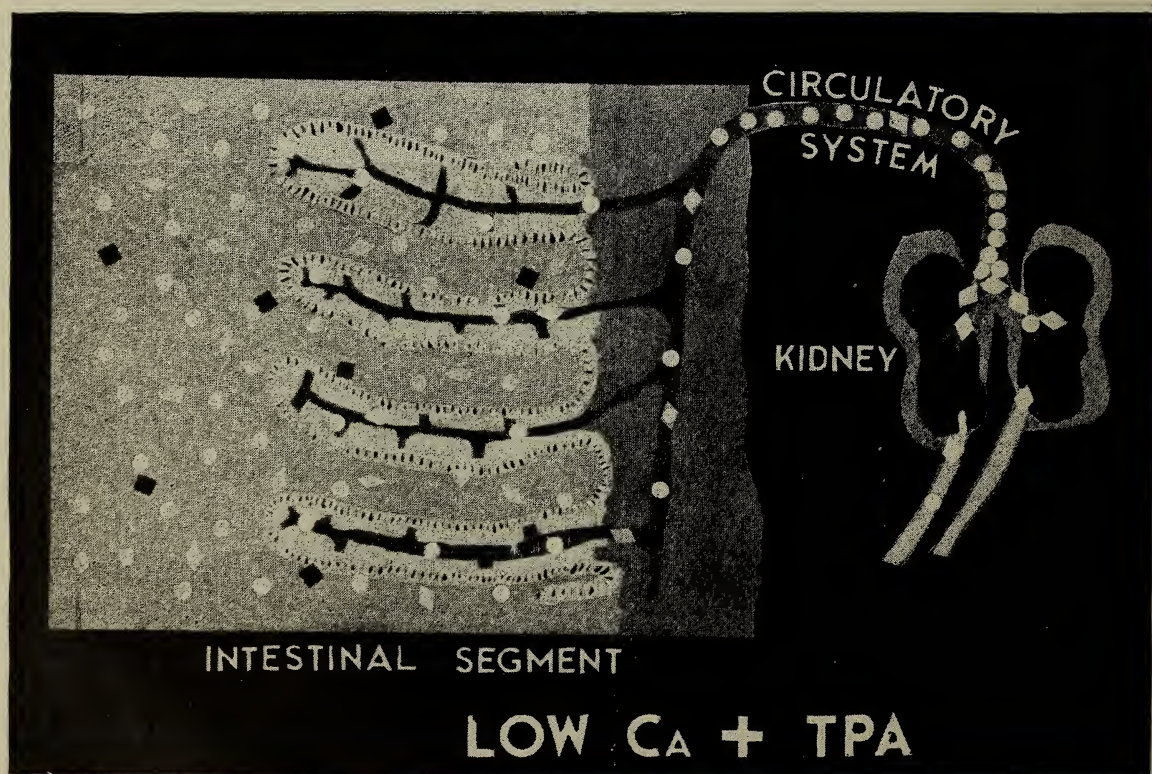
HIGH  $Ca$

*Fig. VII*





*Fig. VIII*



*Fig. IX*



TPA is somewhat less for both antibiotics that is the response to reduced calcium. In the case of both antibiotics, the effects of calcium reduction and TPA addition are additive. The use of reduced calcium level for potentiation has been the subject of a U. S. Patent (36) as has the use of TPA (37). In the U. S. A., the use of TPA has not as yet been approved by the Food & Drug Administration; however, its use has been approved in Canada.

## TEREPHTHALIC ACID MODE OF ACTION

The mode of action of TPA in potentiating antibiotics by influencing renal excretion, is of great interest. 75 % of the oral dose of TPA, fed to dogs, is excreted in the urine in an unchanged condition, suggesting the remaining 25 % was metabolized, as none was recovered from the feces. TPA, unlike most aromatic acids, does not conjugate with glycine (38).

In our hands, TPA evidently has a somewhat more pronounced effect in potentiating broad-spectrum antibiotics in the case of poultry, than with other species (39). The difference between the avian kidneys and those of the mammals might explain this quantitative difference in the action of TPA. As the tubules are a more important route of secretion or excretion in birds than in mammals (40), possibly TPA, which evidently potentiates antibiotics through influencing renal excretion, might be expected to have a somewhat greater effect in poultry.

In rabbits, about one half of tetracycline elimination occurs through tubular secretion (33). In birds, organic acids such as benzoic acid, are detoxified by ornithine rather than glycine (33). If ornithine plays a role in the elimination of the tetracyclines, and if TPA is preferentially conjugated with this amino acid, then tetracycline in the presence of TPA might be less subject to tubular secretion or glomerular filtration.

The mechanism of action of antibiotic potentiation is schematically demonstrated in the following four simplified illustrations (Figure VI through IX) showing a possible mode of action.

In Figure VI, the adsorption of the antibiotic (indicated by small dots) is shown to be high as indicated by the uniform passage of the antibiotic (dots), from the intestinal tract through the villi and into the circulatory system, with subsequent normal urinary excretion following passage through the kidneys. Figure VI represents a diet low in calcium illustrated by the small number of darker squares in the intestinal contents. It is to be noted that in the low calcium control illustration, there is not sufficient calcium (dark squares) to interfere with antibiotics (dots) adsorption.

In contrast, Figure VII illustrates «high calcium» where the increased calcium, shown by the large number of calcium blocks, interferes with antibiotic adsorption. In addition to binding the antibiotic in the intestinal contents, as illustrated by the complexing of the antibiotic by the calcium, the calcium (dark squares) also illustrated as being preferentially adsorbed on the intestinal cell wall. These two illustrated mechanisms of antibiotic interference are in keeping with the experimental data. Also suggested in Figure VII, under these conditions, of calcium inhibition, there is naturally a lowered level of antibiotic in the blood stream indicated by a decreased number of dots in the circulatory system.

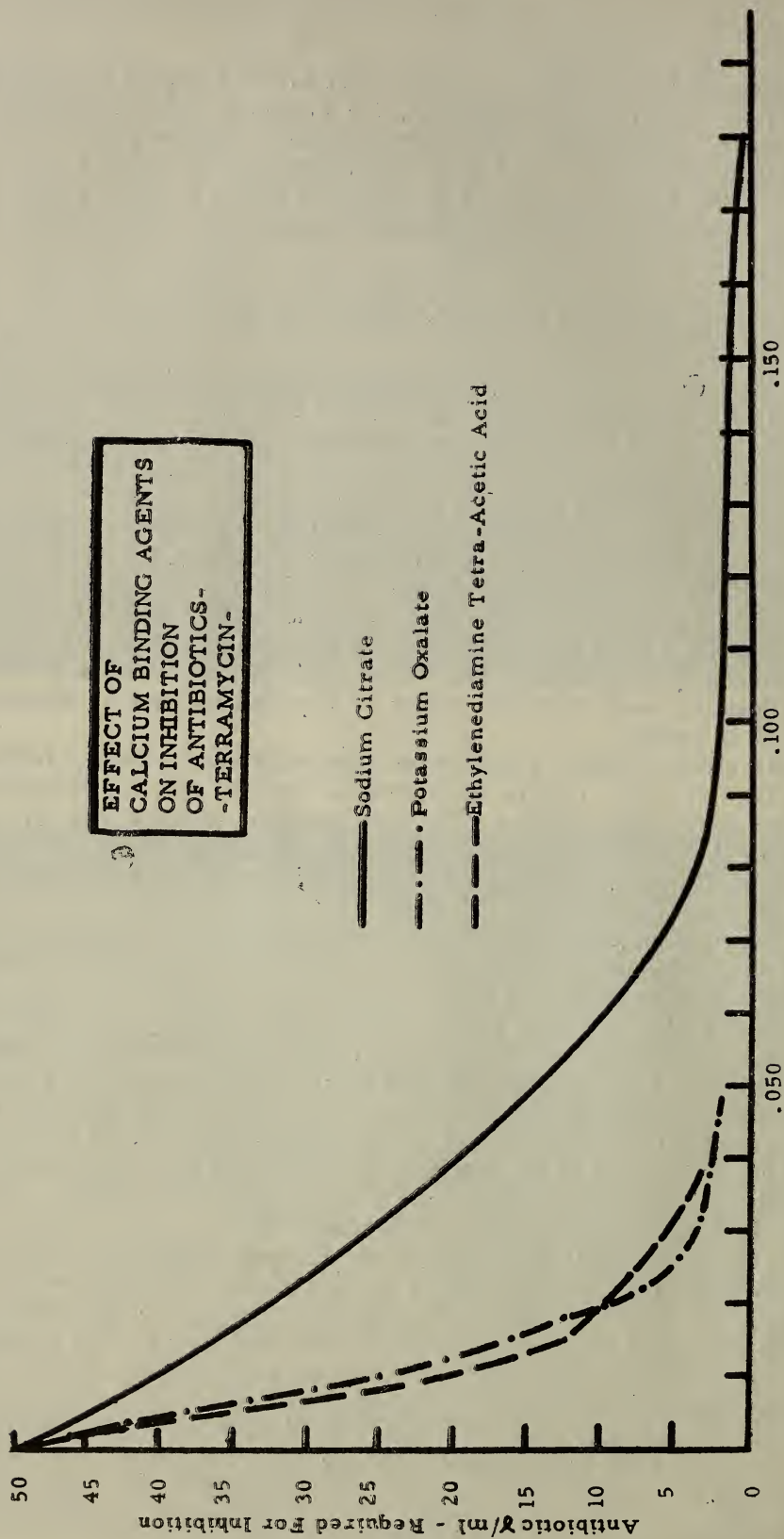


Fig. II



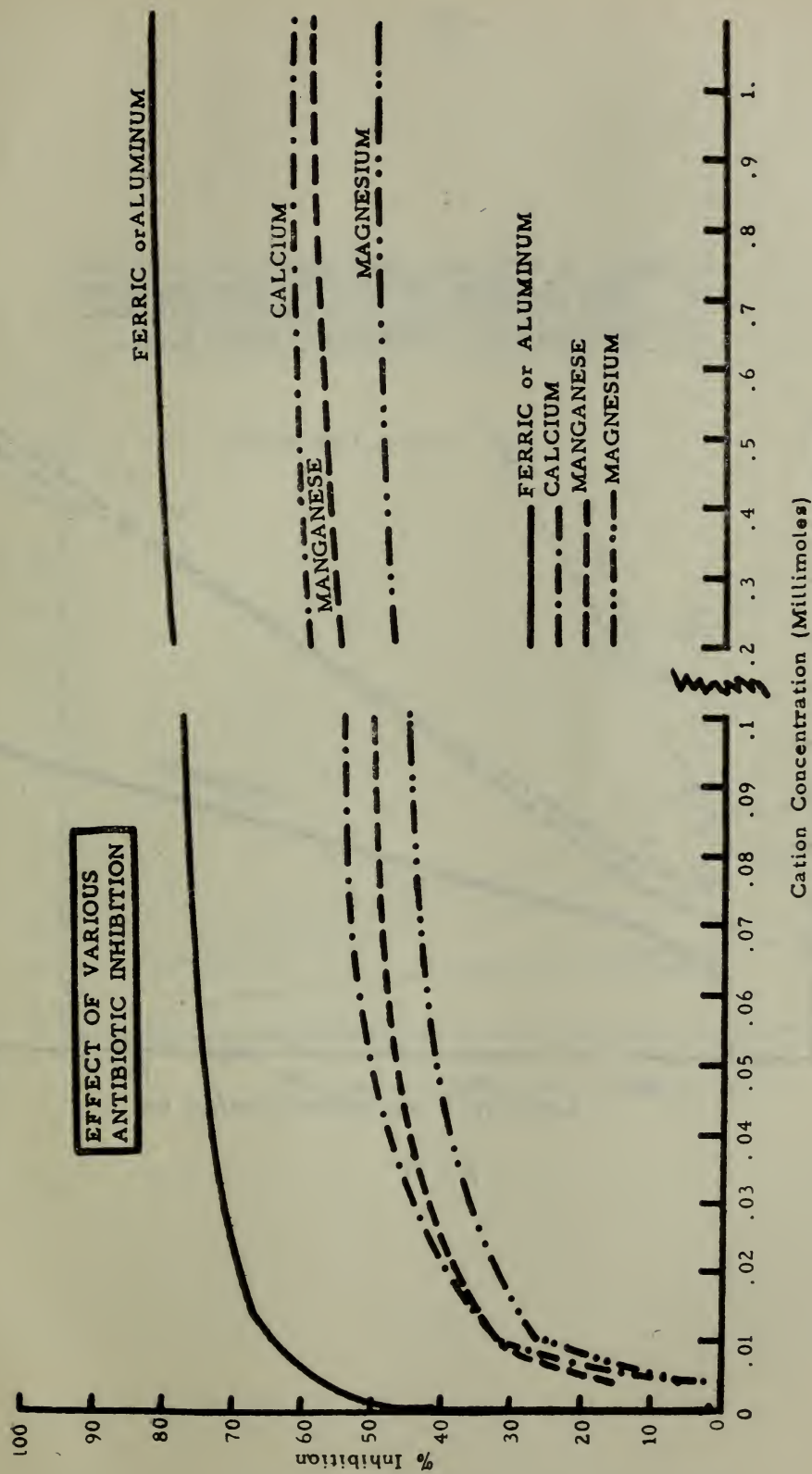


Fig. III

EFFECT OF ANTIBIOTIC CONCENTRATION (0-100,-200,000)  
LEVEL OF CALCIUM (Ca 0.18-1.2%), Terephthalic Acid  
(TPA) (0, 0.3-5%) and their COMBINATION ON BLOOD  
SERUM Levels of Terramycin in Broilers

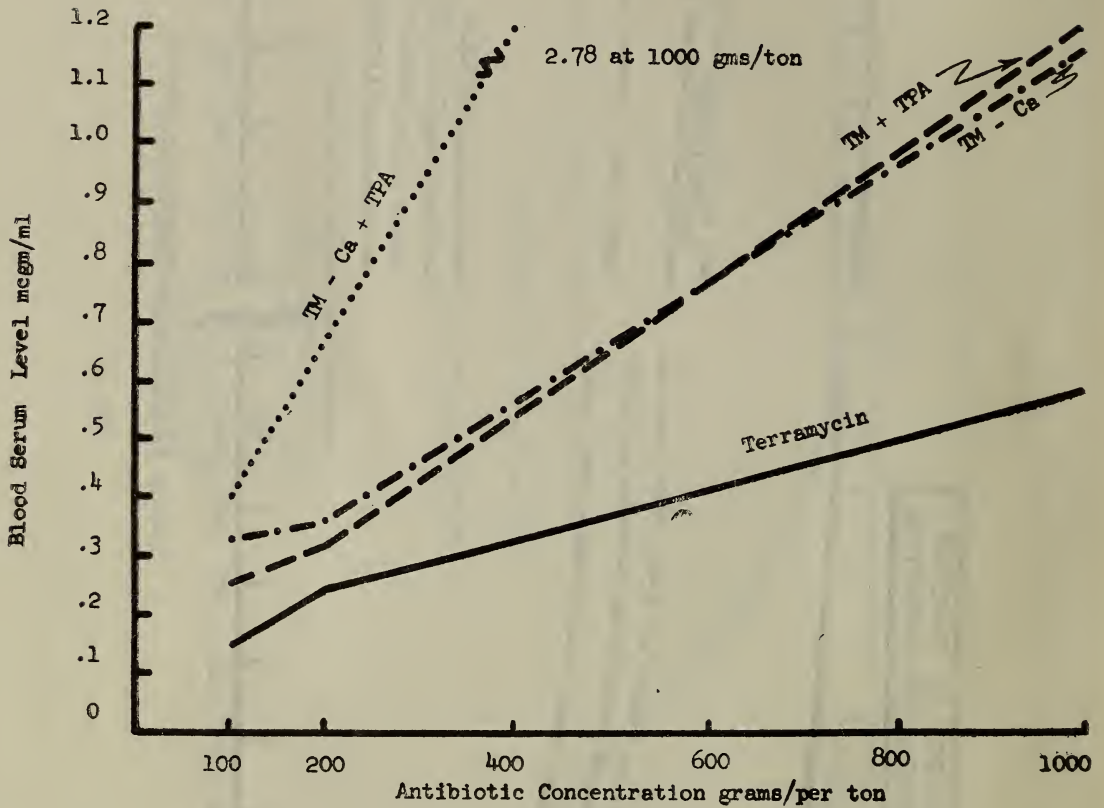


Fig. IV



EFFECT OF ANTIBIOTIC CONCENTRATION (0-100,-200,-000)  
LEVEL OF CALCIUM (Ca 0.18-1.2%); Terephthalic Acid  
(TPA) (0, 0.3-5%) and their COMBINATION ON BLOOD  
SERUM Levels of Aureomycin in Broilers

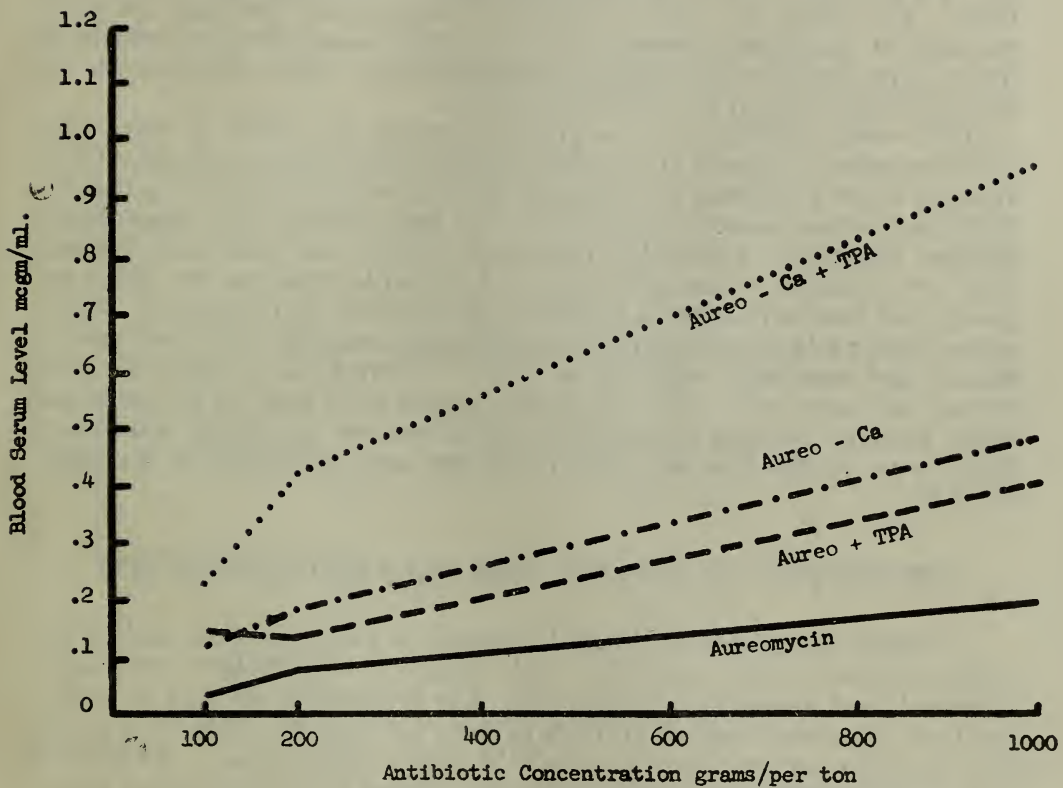


Fig. V

Figure VIII illustrated how calcium inhibition can be reversed by the addition of certain calcium binding or chelating agents, such as citric acid. In this illustration, the citric acid (light colored triangles) binds the calcium (dark squares), rendering the calcium unavailable for hindering adsorption of the antibiotic (dots). With the excess calcium so bound, the antibiotic is again found in its normal level in the blood stream and in the urine.

In Figure IX, the enhancing effect of TPA is illustrated. The TPA molecules (diamond-shaped spots), are shown to act by blocking antibiotic excretion by the kidney. This is shown in the simplified schematic illustration by a physical blocking of the antibiotic (dots) through the accumulation of TPA. The effect of TPA in partially blocking and lowering antibiotic excretion in the urine is shown by the reduced urinary levels of antibiotic (fewer light dots in urine) and by a correspondingly higher concentration of antibiotic (light dots) in the circulatory system.

TPA when investigated as a growth promoter has failed to show any consistent growth response in our hands in studies with poultry, and swine (39). Workers at the University of Arkansas, however, reported an investigation of TPA and related chemical substances. In their studies (42), terephthalic, phthalic, isophthalic, anthranilic, meta-amino-benzoic, and para-amino-benzoic acids were added to rations at the rate of 8 lb./ton to determine the effect on growth and feed conversion in broilers in the presence of Terramycin. Para-amino-benzoic acid depressed growth and increased mortality while meta-amino-benzoic and isophthalic acid had no effect. Terephthalic, anthranilic and phthalic acid along with OTC gave greater weight gains than did the antibiotic alone; however, the growth response of TPA was not statistically significant. There were no blood serum calcium and bone ash differences in the birds fed TPA.

#### SPECIFICITY OF ACTION — TPA RELATED COMPOUNDS

A number of compounds chemically related to TPA have been studied including benzoic acid, isophthalic acid, dimethyl terephthalate, probenecid (Benemid) and parahydroxybenzoic acid. The information obtained in studying these compounds related to TPA is given in Table V. It is to be noted that of all the compounds tests, only TPA showed enhancement. Probenecid and para-aminobenzoic acid both significantly reduced the antibiotic blood serum levels.

Probenecid (dipropylsulfamyl) was included in these studies as it has been reported to be a potentiator for penicillin. It is reported to decrease metabolic destruction and elimination of therapeutically-useful organic acids such as para-aminobenzoic acid by inhibiting their conjugation with glycine. In this case, however, probenecid showed no enhancing effect, and as a matter of fact, actually decreased antibiotic serum concentration. The exact chemical configuration of effective compounds is therefore highly specific according to these results.

Water medication is an important medication route, and therefore the use of soluble forms of TPA is of interest. In addition, there has been some question as to action of TPA being related to its insolubility. The effect of soluble derivatives has been studied and compared to TPA. The potentiating



TABLE IV

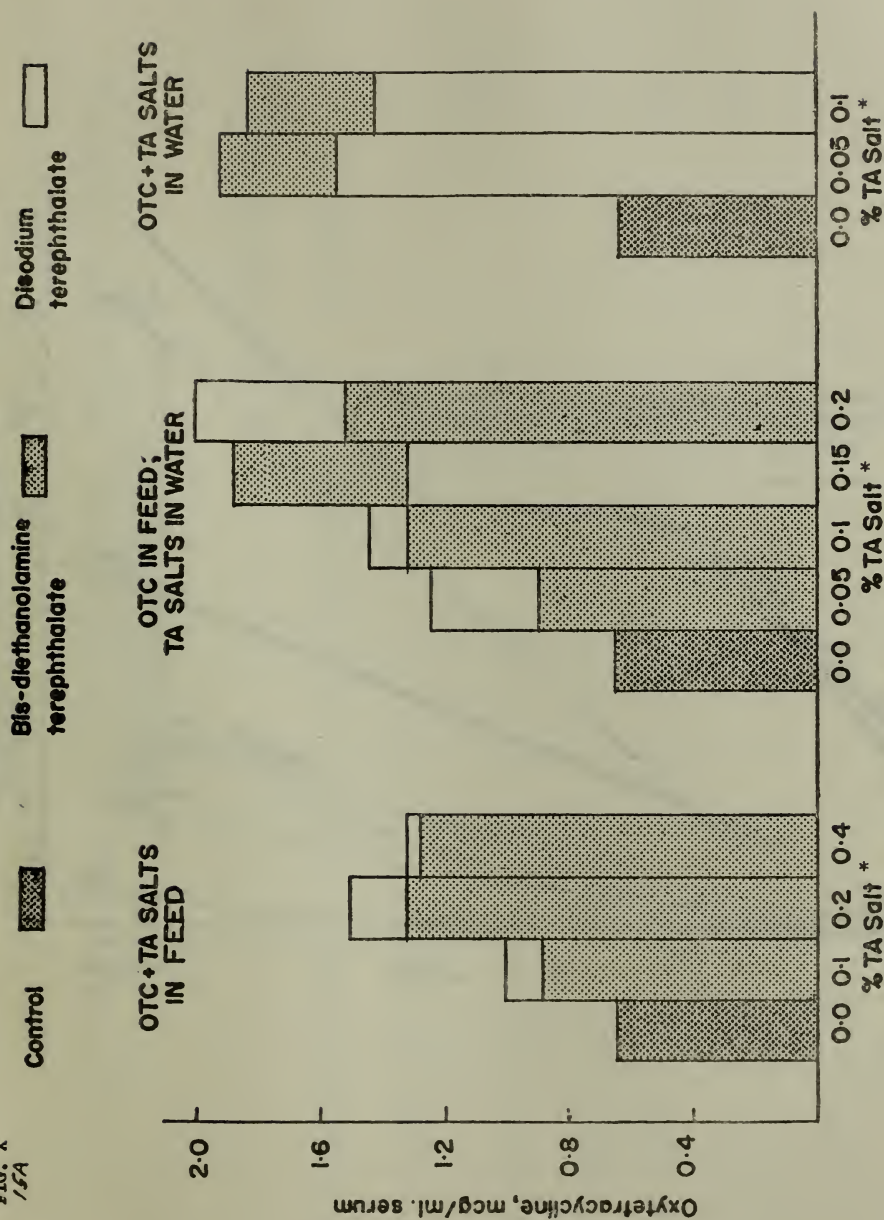
EFFECT OF ANTIBIOTIC CONCENTRATION (0—100, 200 1000) LEVEL OF CALCIUM (Ca 0.18 — 1.2 %), TEREPHTHALIC ACID (TPA) (0 0.3 — 5 %) AND THEIR COMBINATION ON BLOOD SERUM LEVELS FOR AUREOMYCIN AND TERRAMYCIN FOR BROILERS

|                             |       |           |          |               |              | POTENTIATION FROM EXTRA ANTIBIOTIC<br>(per 100 g./ton addition) |       |          |            |               |      |               |            | POTENTIATION FROM TPA ( $\frac{0.33}{10}$ ) |      |               |            |               |      |               |            | Potentiatiou from Calcium Reduction |     |               |            |               |    |               |            | Potentiatiou From Phosphorus Increase |      |               |                       |               |     |               |     |  |
|-----------------------------|-------|-----------|----------|---------------|--------------|-----------------------------------------------------------------|-------|----------|------------|---------------|------|---------------|------------|---------------------------------------------|------|---------------|------------|---------------|------|---------------|------------|-------------------------------------|-----|---------------|------------|---------------|----|---------------|------------|---------------------------------------|------|---------------|-----------------------|---------------|-----|---------------|-----|--|
| ANTIBIOTIC<br>LEVEL g./ton. | Group | Ca<br>0/0 | P<br>0/0 | Ca:P<br>Ratio | TPA<br>Add'n | SERUM LEVELS $\gamma$ /ml.                                      |       |          | TERRAMYCIN |               |      |               | AUREOMYCIN |                                             |      |               | TERRAMYCIN |               |      |               | AUREOMYCIN |                                     |     |               | TERRAMYCIN |               |    |               | AUREOMYCIN |                                       |      |               | TERRAMYCIN AUREOMYCIN |               |     |               |     |  |
|                             |       |           |          |               |              | TERRA                                                           |       | AUREO    | O          |               | TPA  |               | O          |                                             | TPA  |               | Normal     |               | O    | Normal        |            | Ca                                  | O   |               | TPA        |               | O  |               | TPA        |                                       | O    |               | TPA                   |               | O   |               | TPA |  |
|                             |       |           |          |               |              | $\gamma$                                                        | %     | $\gamma$ | %          | $\gamma$ /ml. | %    | $\gamma$ /ml. | %          | $\gamma$ /ml.                               | %    | $\gamma$ /ml. | %          | $\gamma$ /ml. | %    | $\gamma$ /ml. | %          | $\gamma$ /ml.                       | %   | $\gamma$ /ml. | %          | $\gamma$ /ml. | %  | $\gamma$ /ml. | %          | $\gamma$ /ml.                         | %    | $\gamma$ /ml. | %                     | $\gamma$ /ml. | %   | $\gamma$ /ml. | %   |  |
| 100                         | 1     | 1.2       | 0.7      | 1.71          | 0            | .150                                                            |       | .03      |            |               |      |               |            |                                             |      |               |            |               |      |               |            |                                     |     |               |            |               |    |               |            |                                       |      |               |                       |               |     |               |     |  |
|                             | 2     |           |          |               | +            |                                                                 | .252  |          | .141       |               |      |               |            |                                             | .102 | 68            |            |               | .111 | 370           |            |                                     |     |               |            |               |    |               |            |                                       |      |               |                       |               |     |               |     |  |
|                             | 3     | .18       | 0.7      | .26           | 0            | .332                                                            |       | .12      |            |               |      |               |            |                                             |      |               |            |               |      |               |            | .182                                | 121 |               | .092       | 307           |    |               |            |                                       |      |               |                       |               |     |               |     |  |
|                             | 4     |           |          |               | +            |                                                                 | .387  |          | .236       |               |      |               |            |                                             |      |               |            | .055          | 17   |               |            | .114                                | 93  |               | .135       | 53            |    | .095          | 67         |                                       |      |               |                       |               |     |               |     |  |
| 200                         | 5     | 1.2       | 0.7      | 1.71          | 0            | .243                                                            |       | .082     | .093       | 62            |      | .052          | 173        |                                             |      |               |            |               |      |               |            |                                     |     |               |            |               |    |               |            |                                       |      |               |                       |               |     |               |     |  |
|                             | 6     |           |          |               | +            |                                                                 | .319  |          | .140       |               | .067 | 27            |            | .00                                         | 00   | 0.76          | 31         |               | .058 | 71            |            |                                     |     |               |            |               |    |               |            |                                       |      |               |                       |               |     |               |     |  |
|                             | 7     | .18       | 0.7      | .26           | 0            | .358                                                            |       | .197     | .026       | 8             |      | .075          | 61         |                                             | .00  | 00            |            |               |      |               |            | .115                                | 48  |               | .115       | 140           |    |               |            |                                       |      |               |                       |               |     |               |     |  |
|                             | 8     |           |          |               | +            |                                                                 | .661  |          | .422       |               | .274 | 71            |            | .186                                        | 79   |               |            | .303          | 84   |               |            | .225                                | 114 |               | .342       | 107           |    | .302          | 217        |                                       |      |               |                       |               |     |               |     |  |
| 500                         | 9     | 2.25      | 0.55     | 4.10          | 0            | .150                                                            |       | .065     |            |               |      |               |            |                                             |      |               |            |               |      |               |            |                                     |     |               |            |               |    |               |            |                                       |      |               |                       |               |     |               |     |  |
|                             | 10    |           |          |               | +            |                                                                 | .232  |          | .262       |               |      |               |            |                                             | .082 | 55            |            |               | .197 | 302           |            |                                     |     |               |            |               |    |               |            |                                       |      |               |                       |               |     |               |     |  |
| 1000                        | 11    | 1.2       | 0.7      | 1.71          | 0            | .557                                                            |       | .206     | .045       | 30            |      | .0195         | 65         |                                             |      |               |            |               |      |               |            |                                     |     |               |            |               |    |               |            |                                       |      |               |                       |               |     |               |     |  |
|                             | 12    |           |          |               | +            |                                                                 | 1.190 |          | .400       |               | .104 | 42            |            | .029                                        | 20   | .633          | 113        |               | .194 | 94            |            |                                     |     |               |            |               |    |               |            |                                       |      |               |                       |               |     |               |     |  |
|                             | 13    | .18       | 0.7      | .26           | 0            | 1.170                                                           |       | .479     | .093       | 28            |      | .040          | 33         |                                             |      |               |            |               |      |               |            | .613                                | 110 |               | .273       | 133           |    |               |            |                                       |      |               |                       |               |     |               |     |  |
|                             | 14    |           |          |               | +            |                                                                 | 2.780 |          | .950       |               | .266 | 6             |            | .079                                        | 34   |               |            | 1.61          | 138  |               |            | .471                                | 97  |               | 1.59       | 133           |    | .550          | 138        |                                       | .613 | 110           | .165                  | 80            |     |               |     |  |
|                             | 15    | 1.2       | 4.08     | .29           | 0            | 1.17                                                            |       | .371     |            |               |      |               |            |                                             |      |               |            |               |      |               |            |                                     |     |               |            |               |    |               |            |                                       |      |               |                       |               |     |               |     |  |
|                             | 16    | 2.25      | 0.55     | 4.10          | 0            | .345                                                            |       | .093     |            | .039          | 26   |               | .006       | 8                                           |      |               |            |               |      |               |            |                                     |     |               |            |               |    |               |            |                                       |      |               |                       |               |     |               |     |  |
| AVERAGES:                   |       |           |          |               |              | .497                                                            | .832  | .184     | .364       | .058          | 31   | .173          | 52         | .039                                        | 68   | .073          | 33         | .223          | 67   | .656          | 80         | .14                                 | 209 | .27           | 101        | .303          | 93 | .689          | 91         | .16                                   | 193  | .318          | 141                   | .613          | 110 | .165          | 80  |  |





FIG. X  
/5A



\* Free terephthalic acid equivalent

FIG. X The influence of various concentrations of bis-diethanolamine or disodium salts of terephthalic acid (TA) upon serum levels of oxytetracycline (OTC) administered at 500 gm. per ton of feed or 275 ppm. in drinking water.

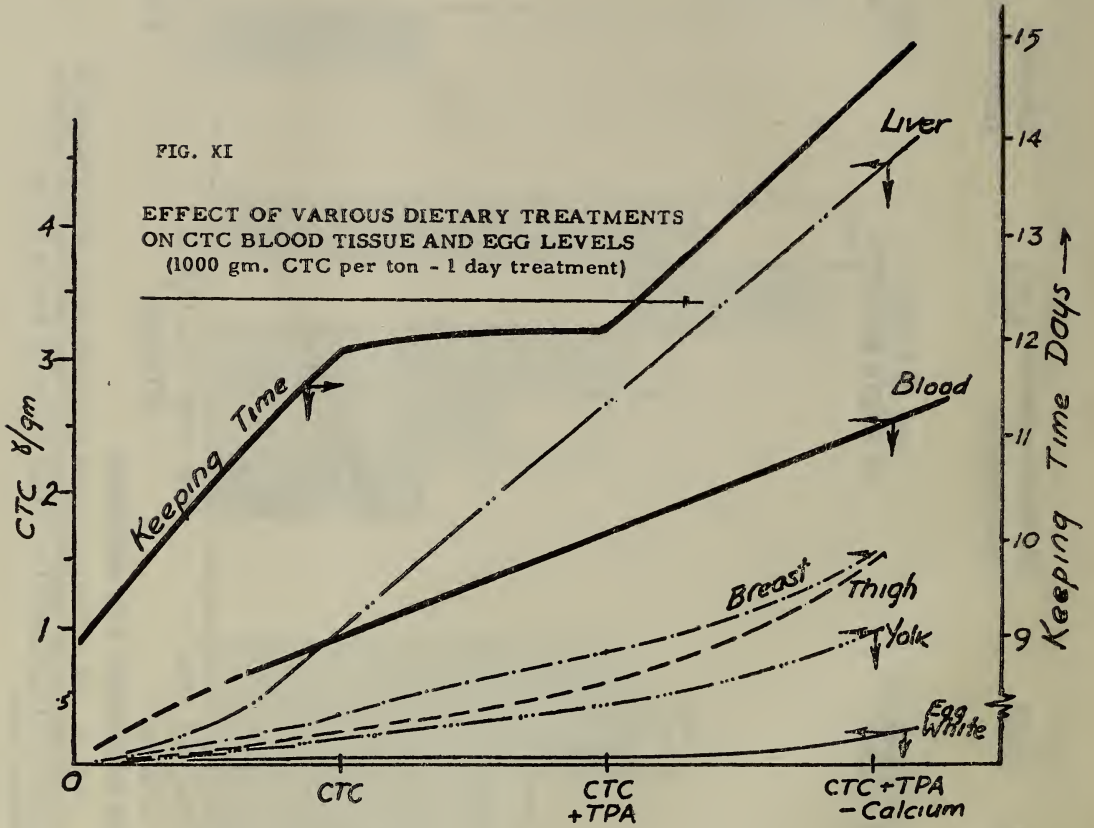
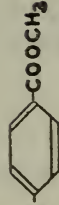
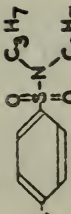


TABLE V

POTENTIATION EFFECT OF COMPOUNDS CHEMICALLY RELATED  
TO TEREPHTHALIC ACID  
(0.4m M-Duodonal Loop Method)

|                   |                                                                                      |  | % IMPROVEMENT      |                |
|-------------------|--------------------------------------------------------------------------------------|--|--------------------|----------------|
|                   |                                                                                      |  | Serum              | Liver          |
| TERRAMYCIN (4 mg) |                                                                                      |  | ----- (0.45% / ce) | - (0.94% / gm) |
| +                 |   |  | 11                 | 4              |
| +                 |   |  | 84 (+)             | 77(+)          |
| +                 |   |  | -8                 | -8             |
| +                 |   |  | -7                 | 36             |
| +                 |   |  | 4                  | 31             |
| +                 |   |  | -32 *              | -7             |
| +                 |  |  | -38 *              | 8              |

(+) = Significant (P.05) increase over Terra

\* = Significant (P.05) decrease from Terra



effect of soluble salts of TPA, the bis-diethanolamine and disodium salts of TPA, as contrasted to the relatively insoluble terephthalic acid, are given in Figure X. These data were obtained by adding the several terephthalic compounds and OTC to the feed and drinking water.

The solubility of the terephthalic compounds is not an important factor in determining the potentiating effect, as both relatively soluble and insoluble terephthalic compounds are potentiators. There is the suggestion that dimethyl terephthalate, which has very slight solubility in water, has somewhat less potentiating effect than the other forms (42a). Soluble salts of TPA are effective potentiators, and water treatment is a possible means of medication.

Data has been developed which shows that potentiation is possible when soluble salts of TPA are injected subcutaneously concurrently with oxytetracycline (42a) (43). Detectable potentiation was observed as early as 3 hours after injection and as late as 24 hours post-injection. Doses of TPA derivatives of 25 to 200 milligrams were employed for antibiotic dosages of 25 and 50 milligrams, and for this range of ratio of potentiator to antibiotic, no effect of TPA salt dosage level was apparent.

## BACTERIAL INVESTIGATIONS OF ANTIBIOTIC INHIBITION AND ACTIVITY

The inhibitory action of various metallic cations on selected antibiotics has been the subject of study. Several hypotheses have been raised as explanations for this phenomenon and they fall into three general categories:

1. Impairment of antibiotic action by high cation concentration thereby exceeding the antibiotics' chelating ability.
2. Impairment of antibiotic action through antibiotic inactivation by formation of cation—antibiotic complex, or compound which renders the antibiotic biologically inactive.
3. Impairment of antibiotic action by preferential adsorption of metallic cation by the bacterial cell.

### A. HYPOTHESIS I.—*The binding ability of the antibiotic through high concentration of metallic cations.*

This hypothesis has as a basic premise, the idea that the antibiotic functions by chelating or binding certain ions that are essential for specific functions. In support of this general hypothesis is the type finding from *in vitro* studies (44) that it is possible to prevent coagulation of blood by chelation of the calcium by the use of very high levels of antibiotic. Antibiotic levels in these *in vitro* studies were higher than those which could be obtained *in vivo*. Both Aureomycin and Terramycin have been shown to interfere with fatty acid oxidation by the mitochondria of the liver cells (45). Magnesium interferes with inhibition of the tetracyclines. This has been interpreted as

antibiotic chelation of magnesium when present at normal concentrations, and removal of this essential element from the biological system. When magnesium is present in high concentrations the antibiotic chelating ability is naturally overwhelmed by the excess of magnesium. The ability of excess magnesium to reverse the inhibition of oxidative phosphorylation in animal tissues by Aureomycin has been similarly analyzed as an exceeding of the antibiotic's chelating ability (46). It is suggested that the antibiotic prevents oxygen uptake by the removal of the essential magnesium ion. When an excess of magnesium is added, normal oxygen uptake is restored. Similar reversal of Aureomycin inhibition of *Escherichia coli* nitro reductase by magnesium has been reported (47).

In vitro tests show that the largest inhibition of the anti-bacterial action of Terramycin was exerted by ferric, ferrous, magnesium and manganese ions (48) (49); similar results have been obtained in our laboratory through our *in vivo* studies with chickens. These authors are all of the opinion that the antibiotic functions through chelation and removal of the essential metallic cation from the bacterial cell, thereby deranging cellular metabolism.

*In vitro* studies in our laboratories indicate similar findings, however extremely high molar ratios of cation inhibition to antibiotics are required in order to obtain much decrease in antibiotic activity. A positive relationship existed between the logarithm of the minimum inhibitory concentration (MIC) of the antibiotic and the logarithm of the inhibiting cation concentration, which could be ideally mathematically expressed by Freundlich's absorption isotherm. The high molar ratios of cation to antibiotic, however, cast some doubt on the appropriateness of this general hypothesis.

B. HYPOTHESIS II.—*Formation of inactive antibiotic-cation complex or compound rendering of antibiotic inactive.*

The magnesium, calcium (50) and iron (4) salts of Terramycin for example possess poor water solubility as contrasted to hydrochloride. Some workers have suggested that cation-antibiotic complexes formed on or in the cell might render the antibiotic non-toxic (51). Other investigations, however, have considered that the antibiotic-cation complex is the actual toxic entity for the bacterial cell instead of the metallic cation (52) and explain the high level of cation required to inhibit antibiotic action on the basis of the greater affinity of the enzyme for the antibiotic-cation complex rather than the metallic cation.

C. HYPOTHESIS III.—*Action through preferential absorption of metallic cation by the bacterial cell.*

Streptomycin uptake studies employing *Micrococcus pyogenes* and sodium chloride established that antibiotic uptake was reduced by sodium chloride (52) (53). The interpretation was that streptomycin uptake occurred almost entirely by absorption on the cell surface. This has been suggested as competition between sodium and streptomycin for absorption centres on the bacterial cell surface (55). Reversal of antibiotic activity in the case of Aureomycin and Terramycin by addition of an excess of magnesium ions to bacterial cells two



hours after exposure to the antibiotic has been interpreted (56) by this same hypothesis. Another interpretation advanced was that the permeability of the cells to certain antibiotics was reduced by the metallic cations.

As existing data does not allow for an unequivocal interpretation of the exact mode of action of antibiotics and their inhibition, additional trials were conducted with washed bacterial cells in an attempt to further clarify the situation (49).

The anti-bacterial action of Terramycin could be reversed by addition of inhibitors such as calcium and magnesium just as easily in the case where the antibiotic and the organism (*Pseudomonas aeruginosa*) had been pre-incubated for 20 hours, as when the inhibitors were added without pre-incubation (28). In these studies magnesium was significantly more inhibitory than calcium, and a linear relationship was found between log of minimum inhibitory concentration (MIC) and log of cation concentration.

Other tests show that it is possible to completely reverse metallic cationic inhibition of Terramycin by the use of materials such as sodium citrate and potassium oxalate, even though the calcium binding agents are added after nine hours of pre-incubation of the antibiotic with excess calcium.

These tests suggest that the antibiotic exerts itself at the surface of the bacterial cell. If the site of the antibiotic activity were intracellular, it would seem unlikely the prompt reversal obtained by delayed addition of sodium citrate and potassium oxalate would occur.

The quantitative determination of Terramycin uptake by washed suspensions of *Pseudomonas aeruginosa* cells, and the effect of exogenous calcium on Terramycin uptake yielded interesting results which are given in Table VI.

TABLE VI

ANTIBIOTIC UPTAKE BY WASHED CELLS AND EFFECT OF EXOGENOUS CALCIUM ON UPTAKE  
(Values in Percent Recovery)

| Cells in<br>Grams | OTC ADDED                     |   | 10 $\gamma$ OTC/ml. |     |      | 40 $\gamma$ OTC/ml. |     |    | 160 $\gamma$ OTC/ml. |     |  |
|-------------------|-------------------------------|---|---------------------|-----|------|---------------------|-----|----|----------------------|-----|--|
|                   | Ca. added<br>( $\gamma$ /ml.) | o | 3.75                |     | 15.0 | o                   |     |    | o                    |     |  |
|                   |                               |   |                     |     |      |                     |     |    |                      |     |  |
| 0                 | 2                             |   | 0                   | 0   | 0    | 19                  | 11  | 13 | 20                   | 23  |  |
| .25               | 56                            |   | 40*                 | 15* | 62   | 27*                 | 37* | 50 |                      | 40  |  |
| .50               | 74                            |   | 73                  | 0*  | 74   | 33*                 |     | 65 | 40*                  |     |  |
| 1.00              | 78                            |   | 74                  |     | 91   | 36*                 | 40* | 88 |                      | 69* |  |

\* = significantly different P = 0.05.

$\gamma$  OTC/ml. = gamma of antibiotic oxytetracycline Hydrochloride added.

Calcium had little effect on oxytetracycline recovery in absence of cells, except some losses occurred at the higher antibiotic concentration. Without calcium, however, antibiotic uptake was increased with increasing number of cells. As calcium concentration increased there was less uptake of antibiotic at all cell concentrations. Similar calcium and antibiotic ratios 3.75 to 10, and 15 to 40 did not show a comparable influence on antibiotic uptake. In the



case of calcium recovery, there was a small but significant uptake of calcium in the presence of cells, significantly influenced, however, by the presence or absence of any concentration of antibiotic.

These data suggest the mode of action of metallic cations in interfering with antibiotic absorption is their preferential absorption by cell. An alternate mechanism is suggested, however, by the results previously presented which quantified the relative inhibition of different antibiotics by calcium. The degree of inhibition can be positively correlated with the calcium complexing ability of the antibiotics; the antibiotics which are inhibited to the greatest extent are those which have the greatest tendency to form cationic complexes. It is not possible therefore to unequivocally designate exactly which mechanism is operative. Naturally, both mechanisms may be operating simultaneously.

### POTENTIATION MEASURED BY DISEASE CONTROL

One of the most practical methods for measuring effective antibiotic potentiation in medication is naturally in the treatment of disease. Many controlled trials have been conducted which have established the definite correlation of potentiation, as measured by enhanced blood level, and by improved disease control. A number of common poultry diseases have been studied in this regard including fowl cholera, coccidiosis, infectious synovitis, chronic respiratory disease, etc.

Numerous trials have now been reported (57) (58) (2) (1) (59). In the case of coccidiosis in poultry, the broad spectrum antibiotics are effective when fed at very high levels, in the order of 500 to 800 gms./ton. It is commercially unfeasible to follow such a practice, however, as a means of treating and preventing coccidiosis. The use of broad-spectrum antibiotics under potentiated conditions, where the blood level of the antibiotic can be significantly enhanced at a practical price, may be of commercial interest. A positive correlation was shown between tetracycline blood level and prophylactic effect of the tetracyclines in experimentally induced coccidiosis, and the potential effect of TPA was demonstrated both in blood level of the tetracycline and the clinical response (60).

In the United States we frequently encounter severe outbreaks of Chronic Respiratory Disease (C. R. D.), and in some of these cases field conditions occasionally exist where the use of higher levels of the broad spectrum antibiotics in the medicated feeds would be desirable for greater efficacy, however, the practicability of such a procedure may be questionable due to the economics involved.

In the presence of C. R. D., broad spectrum antibiotics fed under potentiated conditions has been shown to be of great value in maintenance of rate of gain, desirable feed efficiency as well as reduction in lesion score and unsalable birds. C. R. D. is the most damaging disease condition encountered in raising broilers in the United States, and the use of broad spectrum antibiotics under potentiated conditions is the best prophylaxis and therapy available. In studies with chronic respiratory disease (C. R. D.) chlortetracycline was potentiated 2 to 3 times by TPA based on clinical observation (61). Using weight gain, feed efficiency, lesion score and salable birds as a criteria, additional potentiating effects or both calcium and TPA were observed with oxytetracycline

in controlled challenge trials with C. R. D. (60). In another test (62) evaluating the effect of potentiated and unpotentiated tetracyclines against experimental C. R. D. greater weight response were obtained in the treated groups, but the tetracyclines exerted only slight inhibition of the signs and lesions of the disease.

Low calcium potentiation of oxytetracycline was observed in controlled challenged trials with turkey infectious sinusitis (63). In this trial the reduction of calcium further improved the action of the antibiotic as measured by serological and clinical response. The spread of the disease of the uninfected series was further reduced by lowering of the calcium content of the diet.

In a trial employing chlortetracycline in the treatment of infectious synovitis in the same report (63) the effect of TPA was evaluated by clinical response. The clinical response with 100 grams per ton of chlortetracycline with 0.5 % TPA was as great as with 200 gms per ton of chlortetracycline, and was obtained at a lower treatment cost, based upon the price of the ingredients. Similar potentiation of the oxytetracycline's activity was observed. In evaluating the effect of reduced calcium in a trial with infectious synovitis, 8 days feeding of a low (0.7 %) calcium diet initiated 6 days after inoculation when the signs of the disease became apparent, was shown that both tetracyclines were potentiated (63).

In a controlled challenged trial with infectious synovitis involving both the potentiating effect of TPA and reduced calcium with oxytetracycline both potentiating actions were found to be effective as well as additive. In this trial the antibiotic blood levels were run concurrently, and a positive effect was shown to exist between antibiotic blood levels and clinical response as measured by mortality, lesion score and weight gain (64).

## ANTIBIOTIC ADSORPTION AND KEEPING QUALITY

Considerable work has been conducted which shows that it is possible to increase the keeping time of poultry and livestock meat by the inclusion of low levels of the tetracycline antibiotics. Various methods have been proposed and employed for the inclusion of the antibiotic, the most obvious and initially employed being the dipping of the meat or eggs into a dilute antibiotic solution, or the use of an antibiotic rinse (65). Other methods employed included the post mortem infusion (66), and the ante-mortem infusion (67, 68) of the animal. Comparative keeping qualities with several methods have been reported with oxytetracycline, and all show favorable responses (69). It has been established however that detectable amounts of antibiotics can be retained in the tissue of animals fed high levels of antibiotic (70) (71) (72) (73). If desired, therefore high level feeding of tetracycline antibiotics could possibly offer a means of increasing keeping time of meat. It has been demonstrated for example that feeding 1000 to 2000 parts per million of chlortetracycline resulted in as great an increase in keeping time as did the use of a 10 part per million solution of chlortetracycline hydrochloride (74). This effect has been demonstrated with aureomycin by feeding times as low as one day before slaughter (75).



In studies with the high level feeding (1000 ppm) of chlortetracycline, oxytetracycline, Bacitracin, Penicillin and Streptomycin to chickens (76) significant levels of chlortetracycline, oxytetracycline and Bacitracin were found in the 3 tissues studied, the liver and light and dark meat. Normal cooking destroyed or inactivated the antibiotic in every case. No levels were found in any tissues with the feeding of Penicillin and streptomycin. In this report (76) there were neither apparent difference in bacterial counts nor in keeping qualities.

The antibiotic tissue residues and keeping qualities of meat from high level antibiotic feeding would naturally be expected to be influenced by the presence of inhibitors such as calcium in the diet, and by the presence of potentiators such as TPA in the diet. An interesting paper has just been published which gives data on this point (77). The inclusion of 0.5 % TPA to a ration containing 1000 grams per ton of chlortetracycline resulted in increased absorption of the antibiotic in the blood light and dark meat, and egg yolk and white. The reduction of calcium by withholding of the oyster shell resulted in a more than 100 percent additional increase in adsorption. The keeping time of the meat was related to the antibiotic adsorption running from 9 days for the control to 14 days for the antibiotic fed and 16 days for those receiving antibiotic, low calcium and TPA.

Table VII from (77) gives the levels of both antibiotics in the various tissues, blood, the keeping time of birds fed no antibiotic as well as those supplemented with 0.5 % TPA and those receiving 0.5 % TPA with oyster shell withheld. The normal ration contained 1.1 % calcium.

TABLE VII

ANTIBIOTIC TISSUE CONTENT AND KEEPING TIME POULTRY  
Receiving various dietary treatments (77)

|                     | Control No<br>Antibiotic | Antibiotic<br>(1000 g/ton)<br>CTC | Antibiotic<br>+ 0.5 TPA | Antibiotic<br>+ 0.5 TPA<br>— oyster shell |
|---------------------|--------------------------|-----------------------------------|-------------------------|-------------------------------------------|
| Blood               | —                        | .93                               | 1.73                    | 2.54                                      |
| Egg White           | —                        | .04                               | .04                     | .15                                       |
| Yolk                | —                        | .17                               | .47                     | .95                                       |
| Liver               | —                        | .93                               | 2.74                    | 4.44                                      |
| Thigh               | —                        | .20                               | .58                     | 1.54                                      |
| Breast              | —                        | .33                               | .79                     | 1.35                                      |
| Keeping time (days) | 9                        | 19                                | 12                      | 15                                        |

In this experiment, the residues of antibiotics were desired in order to facilitate an extended storage of the meat. This is in contrast to the interest of the Public Health Official. The use of oral antibiotic fed at «ultra-high» levels for a very short time under potentiated conditions as a means of food preservation, is an interesting new area of research and development. Naturally, some relation exists between blood level and tissue levels of antibiotics.



As a considerable amount of information is available, or can easily be obtained on antibiotic blood level as a function of antibiotic treatment, it would seem desirable to quantify the relationship between blood and tissue levels. With this as an aim, these new published data (77) have been graphed in Fig. XI. In plotting these data the values for straight CTC, CTC + TPA and CTC + + TPA-Calcium are arrayed at equal distances on the abscissa. This is justified on the increasing amount of antibiotic available with increasing potentiated conditions, and is indicated by the practically linear increase in blood level with treatment. This allows for a comparison of blood and tissue levels with feeding method as shown in Fig. XI.

In this case of short term «ultra-high» level oral administration of CTC to poultry, liver levels are higher than blood levels, and with increasing blood

TABLE VIII

EFFECT OF ANTIBIOTIC (1000 g/ton) FED WITH AND WITHOUT 0.5% TPA ON SERUM, EGG YOLK AND WHITE CONTENT (mcgm/ml)  
(Calcium 5 %, P — 0.5 %) (77)

| DAYS FEEDING             | 1        | 2       | 3       | 4        | 7        | Ratio<br>O TPA<br>13 + TPA |     |
|--------------------------|----------|---------|---------|----------|----------|----------------------------|-----|
| <b>CHLORTETRACYCLINE</b> |          |         |         |          |          |                            |     |
| Serum                    |          |         |         |          |          |                            |     |
| CTC                      | .6       | .9      | 1.1     | 1.       |          | 1.                         |     |
| + TPA                    | .3       | 2.0     | 1.0     | 1.9      |          | 1.4                        |     |
| Egg White                |          |         |         |          |          |                            |     |
| CTC                      | 0.04 (2) | L (1)   | .04 (1) | .06 (3)  | .34 (4)  | .16 (4)                    | 1.  |
| + TPA                    | L (1)    | 0.5 (3) | .08 (1) | .16 (3)  | .72 (3)  | .25 (2)                    | 2.0 |
| Egg Yolk                 |          |         |         |          |          |                            |     |
| CTC                      | L (3)    | L (1)   | L (1)   | L-1 (3)  | .4 (4)   | .64 (4)                    | 1.  |
| + TPA                    | L (1)    | L-2 (3) | L (1)   | L (3)    | L-29 (3) | .82 (2)                    | 1.1 |
| <b>OXYTETRACYCLINE</b>   |          |         |         |          |          |                            |     |
| Serum                    |          |         |         |          |          |                            |     |
| OTC                      | 1.6      | 2.0     | 2.1     |          |          |                            | 1.  |
| + TPA                    | 2.6      | 2.9     | 5.3     |          |          |                            | 1.9 |
| Egg White                |          |         |         |          |          |                            |     |
| OTC                      | L (2)    | L (3)   | .59 (1) | .64 (1)  | .67 (2)  | 1.15 (2)                   | 1.  |
| + TPA                    | L (2)    | L (3)   | .86 (5) | 1.09 (2) | 1.17 (2) | 1.45 (2)                   | 1.5 |
| Egg Yolk                 |          |         |         |          |          |                            |     |
| OTC                      | L (2)    | L (4)   | L (1)   | L (2)    | .97 (2)  | 1.05 (2)                   | 1.  |
| + TPA                    | L (2)    | L (3)   | L (6)   | L (2)    | 1.1 (2)  | 1.55 (2)                   | 1.3 |

OTC = Oxytetracycline.

CTC = Chlortetracycline.

L = Below limit of std.

( ) = \*\* of egg analyzed.

TPA = terephthalic acid.

level there is an increasing spread between these values. In comparison to injection of OTC in the tail of beef cattle, however, the poultry tissue and egg contents have a lower antibiotic level than the blood level. Naturally, as indicated by these facts, a considerable amount of data must be accumulated before it is possible to even approximately predict tissue residue levels from blood studies. A study of this relationship would seem profitable, however.

The antibiotic tissue level of oxytetracycline and chlortetracycline as influenced by the presence of 0.5 % TPA, and feeding time is given in Table VIII from the recent work of (77). These data show the potentiating effect of 0.5 % TPA as measured by blood level, egg white and egg yolk for both antibiotics. In this case using a new criteria for measurement of potentiation, namely, the level of antibiotic present in the tissue, we find an average potentiation of 55 % in antibiotic content of egg white and yolk for CTC, and an average potentiation of 40 % for OTC. In the case of the effect of TPA on antibiotic blood serum level, these workers at Ohio State College report a 40 % potentiation of Aureomycin by TPA, and a 90 % potentiation of Terramycin by TPA.

## POTENTIATION OF ANIMALS OTHER THAN POULTRY

There is comparatively little published data available on the potentiating effects of reduced calcium and TPA addition on antibiotics in swine, etc., when compared to the large amount of information available on poultry. A limited amount of information shows that, in general, the same type relationship occur. The responses do not appear to be quite as large in the case of TPA, and in the case of calcium, one would not expect the same degree of response as the calcium levels normally present in the ration of swine are lower than that found in poultry.

In the very young pig there may be some palatability or other problems with the feeding of TPA.

Additional work needs to be done with the potentiation of antibiotics in other animals. It seems that the same general relationship appear to hold, but the response may not be as large.

## CALCIUM REDUCTION

Obviously the most economical means of potentiating the tetracyclines and some other antibiotics is by reduction in the amount of the inhibitor, calcium, in the diet. This is naturally not without limitations due to the animal requirement for the essential mineral.

The use of reduced calcium is of special interest, for in addition to favorable cost, there are no regulatory restrictions as may be the case with TPA. In the United States, for example, the use of TPA in feeds has not been approved. In Canada on the other hand, the inclusion of TPA in medicated feeds has been sanctioned.

The short term feeding of diets low in calcium is practical for many periods in the life span of animals. The tolerance of the broiler for various levels of reduced calcium of from 0.14 to 0.9 % calcium, for periods of two to 18 days during different parts of the growing period is given in Table IX.

TABLE IX

EFFECT OF CALCIUM REDUCTION ON GROWTH RATE OF BROILER CHICKS  
AT VARIOUS PERIODS AND VARIOUS AGES

(Expressed as % of Optimum Growth on 1.1 % Calcium — 100 % weights)

| PERIOD OF CALCIUM<br>REDUCTION |                   | 0/0 OF OPTIMUM GROWTH (8 weeks) |        |        |        |        |         |
|--------------------------------|-------------------|---------------------------------|--------|--------|--------|--------|---------|
| Age of animal<br>(days)        | Number<br>of days | Calcium Level (0/0 Ca           |        |        |        |        |         |
|                                |                   | .9 0/0                          | .7 0/0 | .6 0/0 | .4 0/0 | .2 0/0 | .14 0/0 |
| 0 — 2                          | 2                 |                                 |        | 95     |        | 99     |         |
| 0 — 4                          | 4                 |                                 |        | 99     |        | 99     |         |
| 0 — 8                          | 8                 |                                 |        | 100    |        | 94     |         |
| 0 — 14                         | 14                | 98                              | 88     |        | 84     |        |         |
| 0 — 28                         | 18                |                                 |        | 84     |        |        | 63      |
| 32 — 36                        | 4                 |                                 |        | 96     |        | 98     |         |
| 32 — 40                        | 8                 |                                 |        | 98     |        | 100    |         |
| 56 — 60                        | 4                 |                                 |        | 96     |        | 97     |         |
| 56 — 64                        | 8                 |                                 |        | 100    |        | 99     |         |

The extended feeding of diets too low in calcium is naturally impractical, however, short term feeding of even quite low levels of calcium appear to be tolerable based upon 8 week weight gains.

Information on intermediate weight gains of growing chicks and on the bone ash at eight weeks is given in Table X, adapted from (79). Bone ash seems to be influenced only when the calcium was lowered in the period immediately preceding the test period for bone ash determination.

It is obvious that short term reduced calcium feeding is a practical basis for potentiation of the tetracycline in the case of broilers. In the United States dietary calcium adjustment is practiced commercially as a means of increasing the activity of certain antibiotics in medicated feeds. It appears that some of the ideas on calcium requirement of the growing chick might be revised towards lower levels of calcium. In the case of the laying hen there is an immediate, but apparently transient effect on egg production from calcium reduction. There was approximately a 10 % reduction in rate of lay during a 5 day low calcium regimen (0.12 % calcium). In the 6 week period following the low calcium treatment there were no signs of decreased lay (79). The reduction of calcium from laying hens is an area which should undoubtedly be approached with caution.



TABLE X

EFFECT OF SHORT TERM FEEDING 0.2 % AND 0.6 % CALCIUM CONTENT DIET TO GROWING CHICKS ON WEIGHT AND BONE ASH (19)

(Weight response Control 1.2 % Ca = 100 %)

| Period of $\frac{0}{0}$<br>Low Calc. Calc. |     |     | $\frac{0}{0}$ Growth Response of Control (1.2 $\frac{0}{0}$ Ca) |     |      |     |     |     |      |     | $\frac{0}{0}$ Bone<br>Ash |
|--------------------------------------------|-----|-----|-----------------------------------------------------------------|-----|------|-----|-----|-----|------|-----|---------------------------|
| Time Days                                  | Wks |     | 1                                                               | 2   | 3    | 4   | 5   | 6   | 7    | 8   | (8 weeks)                 |
| Control                                    | —   | 1.2 | 100                                                             | 100 | 100  | 100 | 100 | 100 | 100  | 100 | 56.7                      |
| 0-2                                        | 2   | 0.2 | 106*                                                            | 103 | 101  | 101 | 101 | 101 | 101  | 100 | 57.4                      |
| 0-2                                        | 2   | 0.6 | 97                                                              | 100 | 101  | 100 | 99  | 98  | 98   | 96  | 56.8                      |
| 0-4                                        | 4   | 0.2 | 98                                                              | 100 | 102  | 100 | 99  | 101 | 102  | 100 | 56.3                      |
| 0-4                                        | 4   | 0.6 | 104                                                             | 103 | 104  | 104 | 104 | 102 | 101  | 98  | 56.3                      |
| 0-8                                        | 8   | 0.2 | 92*                                                             | 91* | 94*  | 97  | 98  | 94  | 95   | 95  | 57.2                      |
| 0-8                                        | 8   | 0.6 | 102                                                             | 103 | 105* | 104 | 105 | 103 | 102  | 100 | 57.3                      |
| 28-32                                      | 4   | 0.2 |                                                                 |     |      | 99  | 99  | 96  | 99   | 99  | 57.4                      |
| 28-32                                      | 4   | 0.6 |                                                                 |     |      | 100 | 101 | 98  | 96   | 94  | 56.7                      |
| 28-36                                      | 8   | 0.2 |                                                                 |     |      | 103 | 104 | 101 | 103  | 100 | 57.1                      |
| 28-36                                      | 8   | 0.6 |                                                                 |     |      | 101 | 102 | 98  | 98   | 97  | 57.1                      |
| 49-53                                      | 4   | 0.2 |                                                                 |     |      |     |     |     | 100  | 98  | 57.1                      |
| 49-53                                      | 4   | 0.6 |                                                                 |     |      |     |     |     | 96   | 96  | 56.9                      |
| 49-57                                      | 8   | 0.2 |                                                                 |     |      |     |     |     | 99   | 97  | 55.8*                     |
| 49-57                                      | 8   | 0.6 |                                                                 |     |      |     |     |     | 102  | 98  | 56.0*                     |
| Average                                    | 5.1 | 0.4 | 100                                                             | 100 | 101  | 101 | 101 | 99  | 99.5 | 98  | 56.8                      |

\* Significantly different than control.

In addition to the level of calcium in the ration the type of calcium employed is evidently a factor in determining the amount of inhibition of the tetracyclines (80) (81) (82).

The data in Table XI give the effect of various levels of different calcium compounds upon the resulting Terramycin blood serum level when Terramycin was fed at 1000 gms per ton (80).

The effect of various Calcium salts and mixtures on the resulting blood serum levels of Aureomycin is given in Table XII. Calcium salts at a level of 0.6 % Ca were added to give a total calcium level of 1.0 % Ca to the ration which contained 200 grams per ton of Aureomycin.

The water intake of poultry is not influenced by the amount of calcium carbonate in the ration, however it is markedly increased with increasing levels of calcium sulfate, showing a 63 % increase in water intake when calcium sulfate furnishes 1.17 % calcium (81). Complete replacement of calcium carbonate has been reported to increase litter moisture by 33 % (82). Its inclusion in poultry rations must therefore be done with care. Fats and fatty acids which are known to influence calcium utilization have been tested

TABLE XI

EFFECT OF VARIOUS LEVELS OF DIFFERENT CALCIUM SOURCES ON ABSORPTION  
OF ORALLY ADMINISTERED TERRAMYCIN

TM = 1000 gm/ton of feed P in basal = 0.31 % Ca in basal — 0.16 %

Adapted from (80)

Terramycin Serum Concentration mcgm/ml and Relative Level ( )  
with  $\text{CaCO}_3$  at 1.16 % Ca = 100

| Calcium Source |           | Dietary Calcium Level |           |           |           |           |
|----------------|-----------|-----------------------|-----------|-----------|-----------|-----------|
|                |           | 0.16                  | 0.41      | 0.66      | 0.91      | 1.16      |
| None           |           | 2.46(2.0)             |           |           |           |           |
| Calcium        | Carbonate |                       | 2.61(2.1) | 2.28(1.8) | 1.58(1.3) | 1.24(1.0) |
| »              | Sulfate   |                       | 2.63(2.1) | 2.68(2.1) | 2.23(1.8) | 2.03(1.6) |
| »              | Gluconate |                       |           | 2.35(1.9) |           | 1.79(1.5) |
| »              | Chloride  |                       |           | 2.09(1.7) |           | 1.70(1.3) |
| »              | Lactate   |                       |           | 1.63(1.3) |           | 1.82(1.5) |
| »              | Citrate   |                       |           | 2.01(1.6) |           | 1.85(1.5) |
| »              | Oxide     |                       |           | 1.43(1.2) |           | 1.91(1.5) |

TABLE XII

EFFECT OF VARIOUS CALCIUM SALTS ON AUREOMYCIN BLOOD SERUM LEVELS (81)

| Calcium Source |                            | Aureomycin<br>mcgm/ml | Relative level <sup>1</sup><br>$\text{CaCO}_3$ —10 |
|----------------|----------------------------|-----------------------|----------------------------------------------------|
| None           |                            | 0.29                  | 2.5                                                |
| Calcium        | Carbonate                  | 0.11                  | 1.0                                                |
| »              | Oxide                      | 0.10                  | 0.9                                                |
| »              | Chloride                   | 0.11                  | 1.0                                                |
| »              | Sulfate                    | 0.18                  | 1.6                                                |
| »              | Gluconate                  | 0.29                  | 2.6                                                |
| »              | Lactate                    | 0.21                  | 1.9                                                |
| »              | Carbonate — Sodium Sulfate | 0.16                  | 1.5                                                |
| »              | Sulfate — Calc. Carbonate  | 0.19                  | 1.7                                                |
| »              | Carbonate — Sulfuric acid  | 0.20                  | 1.8                                                |

for potentiating effect. Stearic acid when added at 5 and 10 percent in the ration had a potentiating effect on oxytetracycline (82).

Another interesting area for possible potentiation of antibiotics has been opened by recent repeated work with soft (colloidal) phosphate (83) (84). Recently it has been shown that up to 75 % of the usual level of phosphate in poultry diets added as dicalcium phosphate can be replaced with soft phosphate (83).

In trials employing soft phosphate as a partial replacement for dicalcium phosphate a high degree of potentiation of Terramycin was obtained (84). These data are given in Table XIII. They show the additive effect of TPA, and in these trials TPA shows as average potentiation of 123 %, and the use of soft phosphate showed an average enhancement of 80.7 % as a partial replacement for dicalcium phosphate.

TABLE XIII

THE EFFECT OF COLLOIDAL (SOFT) PHOSPHATE AND DICALCIUM PHOSPHATE IN CHICK DIETS ON BLOOD LEVELS OF TERRAMYCIN

(All rations 1.0 % Ca 0.6 P 400 g./ton Terramycin)

adapted from (84)

| Dical. Phos. | Soft Phos. | TPA % | Gains (g.)<br>4 week | Terramycin<br>Blood Level<br>(mcg./ml) | % Improvement |                           |
|--------------|------------|-------|----------------------|----------------------------------------|---------------|---------------------------|
|              |            |       |                      |                                        | Due to TPA    | Due to soft P,<br>Substit |
| .485         | 0          | 0     | 500                  | 0.128                                  |               |                           |
| .323         | .162       | 0     | 491                  | 0.183                                  |               | 43                        |
| .162         | .323       | 0     | 493                  | 0.254                                  |               | 98                        |
| .485         | 0          | .40   | 525                  | 0.263                                  | 103           |                           |
| .323         | .162       |       | 543                  | 0.488                                  | 166           | 85                        |
| .162         | .323       |       | 464                  | 0.509                                  | 100           | 94                        |
|              |            |       |                      | AVERAGE                                | 123 %         | 807 %                     |

Further study is necessary to pinpoint the exact mechanism involved in these various calcium sources which allow for greater tetracycline utilization. Possible explanations are that the less soluble salts might yield a lower calcium ion concentration (81), and that calcium is released more slowly from these compounds giving a smaller concentration of calcium ions at the anterior portion of the intestinal tract where antibiotic adsorption is maximal (82). The possibility exists that these compounds may actually have a lower availability and in some cases potentiation may result from an actual reduction in the available calcium and/or phosphorus being given. In the case of soft phosphate for example the apparent digestibility of the phosphorus is lower than in dicalcium phosphate, and there is a decreased availability of calcium. In such cases it is possible that the calcium to phosphorus ratio is also being altered, as well as the level of available calcium, and it is known that a lower calcium to phosphorus ratio will also favorably influence antibiotic availability (4).

## PRACTICAL POTENTIATION PROCEDURES

In the United States high level antibiotic medicated feeds with reduce levels of calcium are widely used for short periods of time. They actually afford a means of following this prevention and treatment program to meet the specific stress and disease problems that are peculiar to a particular operation.



Usually, in such a program the birds are started for the first 4 or 5 days on a high level antibiotic potentiated feed from day of age to avoid early chick and poult mortality and anticipation of stresses which may occur. Similarly, a 4 or 5 day potentiated high level antibiotic feed might be used at around the time of the second vaccination, and a third short term prophylactic feeding of 4-5 days might be employed at about 7 weeks of age, as respiratory or other setbacks are usually encountered at this time. By following such a prophylactic program the protection from high level antibiotics is available at those times when it normally encounters disease and stress difficulties. Naturally, this program can be modified to meet any particular needs. In addition, potentiated high level antibiotics are fed for short times of up to 5 days should an antibiotic susceptible disease outbreak occur.

As previously discussed there are problems associated with even the short term reduction of calcium in the ration of the laying hen. Is an attempt to minimize or obviate the difficulties inherent to lowering of the calcium level in the diet methods such as restricting the period of feeding a low calcium to a few hours in the day have been attempted.

A recent report has been made (85) comparing the results of a restricted feeding program to laying hens with those obtained with the usual calcium reduction the restricted method employing a very high level of oxytetracycline (1000 grams per ton of feed), and a very low level of calcium (0.11 %) fed for only the first three hours of the day followed by the normal ration for the remainder of the day. In the usual reduced calcium program 200 grams of oxytetracycline were continuously fed in a low calcium diet (0.5 % Ca). Egg production, egg weight, shell strength and shell thickness and antibiotic serum levels were measured in all cases and compared to the appropriate controls. The results are given in Table XIV and show the data obtained in the 3 day pretreatment, the 5 day treatment, and the 3 day post-treatment period for all criteria studied.

On continuous low level calcium feeding (0.5 % groups 3 + 4) there is a suggestion of possibly unfavorable influence on egg production during the treatment period. The favorable effect of oxytetracycline on egg production rate is evidenced in the post treatment period, as group 4 shows good production, and group 3 shows a decrease in production. The greatest overall percentage in egg production was attained in group 2, the 3 hour restricted feeding program.

The relative improvement in egg production in the low calcium plus antibiotic (group 4) as compared to the low calcium control (group 3) suggests a possible calcium sparing effect of the antibiotic. This is in keeping with the reports of improved calcium adsorption in rats fed a low calcium diet (86); and the report that penicillin added to the diet of hens increased the calcium level in the blood serum and egg shell breaking strength (87).

Birds on both types of continuous low calcium diet (groups 4 + 5) produced eggs of lower weight, with the group containing low calcium and no antibiotic showing the greatest decrease. Both groups returned to normal weight egg production during the post treatment period. The group on the restricted very low calcium high antibiotic diet showed no unfavorable effect of egg weight.

Similarly, egg shell thickness and egg shell strength showed a drop during the treatment period for both continuous low calcium diets, with the group

TABLE XIV

EFFECT OF VARIOUS LOW CALCIUM AND HIGH ANTIBIOTIC FEEDING METHODS ON BLOOD SERUM LEVELS, EGG PRODUCTION, EGG WEIGHT, SHELL STRENGTH, THICKNESS AND FEED INTAKE

| Group                    | adapted from (85) |                                 |                        |                      |
|--------------------------|-------------------|---------------------------------|------------------------|----------------------|
|                          | 1<br>Cont. A      | 2<br>Restr. very<br>low Ca—OTC  | 3<br>Cont. 8<br>low Ca | 4<br>Low Ca<br>— OTC |
| % Ca                     | 3.28              | 0.11 (3 hrs.)<br>3.28 (21 hrs.) | 0.5                    | 0.5                  |
| Antib. (OTC) g/t         | 0                 | 1000 (3 hrs.)<br>0 (21 hrs.)    | 0                      | 200                  |
| Egg Production (%)       |                   |                                 |                        |                      |
| Pretest                  | 49                | 46                              | 45                     | 61                   |
| Treat                    | 54                | 55                              | 48                     | 63                   |
| Post-test                | 58                | 62                              | 46                     | 72                   |
| Egg Weight (gms)         |                   |                                 |                        |                      |
| Pretest                  | 57.6              | 54.6                            | 56.2                   | 57.6                 |
| Treat                    | 57.3              | 56.2                            | 55.8                   | 56.7                 |
| Post-test                | 57.0              | 56.0                            | 56.6                   | 57.8                 |
| Egg Shell Strength (lbs) |                   |                                 |                        |                      |
| Pretest                  | 9.70              | 8.88                            | 9.60                   | 9.87                 |
| Treat                    | 9.84              | 10.13                           | 8.65                   | 9.16                 |
| Post-test                | 9.92              | 10.20                           | 9.86                   | 9.76                 |
| Egg Shell Thick (in)     |                   |                                 |                        |                      |
| Pretest                  | .0138             | .0138                           | .0139                  | .0141                |
| Treat                    | .0138             | .0141                           | .0121                  | .0130                |
| Post-test                | .0138             | .0133                           | .0132                  | .0122                |
| Feed Consumption ( /day) |                   |                                 |                        |                      |
| Pretest                  | .22               | .21                             | .20                    | .22                  |
| Treat                    | .26               | .25                             | .23                    | .26                  |
| Post-test                | .28               | .25                             | .22                    | .25                  |
| Serum                    |                   |                                 |                        |                      |
| Blood Level mcgm/ml      |                   |                                 |                        |                      |
| Day 1   0 hrs.           |                   |                                 |                        |                      |
| 1                        | —                 | .402                            |                        |                      |
| 2                        | —                 | —                               |                        |                      |
| 3                        | —                 | .562                            |                        |                      |
| 5                        | —                 | .451                            |                        |                      |
| 7                        | —                 | .315                            |                        |                      |
| Day 3   0                | —                 | —                               | —                      | .393                 |
| Day 4   0                | —                 | —                               | —                      | .267                 |

Footnote: = no zone <.07502  
<.12

receiving no antibiotic showing the greatest drop. In each criterion the inclusion of oxytetracycline shows a definite value in minimizing or eliminating the undesirable effects of continuous low calcium administration. It is significant that the restricted very low calcium regimen showed no setback in any instance.

In the case of blood serum levels it is noted that a high potentiated level averaging 0.35 mcgm/ml. is obtained on the continuous low calcium feeding. The use of such a program has dangers as shown by the effect on egg production, egg weight, egg shell strength and thickness, etc. While it gives excellent blood levels as compared to normal feeding practice, the use of such a program is dangerous. With the use of a restricted feeding program employing a very low calcium level for a few hours a day it is possible to obtain the benefits of the high blood serum level without the untoward effects. In the 3 hour restricted program reported (85) very high levels were obtained for up to seven hours after medication; however, the restriction of feeding to 3 hours is too short to give a continuous detectable level. Increasing the restricted feeding time to 4 or 5 hours apparently allows for a detectable blood levels at all times, and give continuity of antibiotic blood serum level.

Naturally restricted programs are more difficult feeding practices and incur higher labor costs. In the final analysis in commercial practice economic considerations are those which largely govern selection of potentiation procedures. It is really a matter of attaining the highest blood serum level at the lowest cost for the prevention and treatment of systemic diseases. There are many alternate methods and different adjuvants available for enhancing blood serum levels, all of which incur different material, labor and production costs.

## SUMMARY

The divalent cations present in feed can inhibit the activity of many antibiotics. Calcium is the most important inhibitor from a practical standpoint, due to the high level in which it is present in many rations.

Calcium shows varying degrees of inhibition with different antibiotics, penicillin being almost unaffected, followed in increasing order of inhibition by chloramphenicol, bacitracin, oleandomycin, oxytetracycline, chlortetracycline, dihydrostreptomycin and neomycin. Their degree of inhibition is evidently related to their calcium complexing ability. Due to their broader spectrum of activity in prevention and treatment of disease the tetracyclines have been studied in detail. It is possible for example in medicated high level antibiotic rations for broilers to double the activity of the antibiotic by a temporary reduction for 4 or 5 days of the calcium levels to approximately 0.4 % - 0.5 % calcium. Calcium as other cations probably acts as an inhibitor by complexing with the antibiotics. There is also a preferential cell adsorption of calcium in comparison to the tetracyclines. Both level and source of calcium are factors as calcium sources other than the carbonate produce a smaller degree of inhibition. Calcium sulfate, gluconate, citrate, etc. and soft (colloidal), phosphate are possible antibiotic potentiators, however, cost, wet droppings, and availability must be considered. Calcium reduction must be planned to avoid prolonged upsetting of the animals basic nutritional requirements. Growing chicks exhibit considerable tolerance for low calcium diets of up to 8 days,



however laying birds show a noticeable but evidently transient reduction in rate of lay.

Terephthalic acid (TPA) is a potentiator which acts through a different mechanism, evidently by decreasing antibiotic urinary excretion, and therefore its effects are additive to those obtained by reduced calcium interference. TPA when added at optimum levels of 0.35 to 0.5 % has resulted in approximately a doubling of the blood serum level obtained from the feeding of high levels of tetracyclines to poultry. The use of TPA is not sanctioned in the United States of America but is allowed in Canada.

These potentiation principle, largely developed and tested in poultry apply to other animals as swine, however the degree of response is probably less. The degree of calcium interference in non poultry rations would also be less due to lower calcium levels in the normal diet.

Published work is limited in other species.

Potentiation of antibiotics has been demonstrated by bacteriological procedures, by blood serum, and tissue levels measurements, and of more practical importance, by prevention and treatment of several commercially important diseases. Poultry diseases such as chronic respiratory disease, infectious synovitis, sinusitis, fowl cholera, coccidiosis have been treated more efficiently by antibiotics under potentiated conditions. In recent laboratory trials feeding extremely high levels of antibiotics of 1000 grams per ton under potentiated conditions has increased the keeping time of poultry meat.

## «QUESTIONS AND ANSWERS»

1. By — Dr. G. Varela — Spain:

Is potentiation of antibiotics through reduced calcium procedures a practice which is followed in the United States?

Yes. It is rather widely used for short term medication especially in the poultry field. This is dictated by the low cost of the treatment and the fact that other potentiators such as terephthalic acid (TPA) are not allowed in the U. S., and calcium binding agents are impractical from a cost standpoint. This method is fairly widely practiced, in limited feeding medication programs with broilers. Naturally, care must be exercised in following reduced calcium treatment to honor the nutritional requirements of the animal. However, short term disruption of calcium intake can be tolerated by broilers. We are finding that the conventional calcium levels for broilers of approximately 1.3 % may be considerably higher than necessary. Calcium sulfate as a potential calcium salt is being used to some extent as is the use of soft phosphate. However, in these cases, one must pay attention to the potential problem of wet droppings, as well as be aware of availability problems.

2. By — Dr. Gallo, Spain.

What is the status regarding the approval of TPA? Is it a practical feed additive?

Terephthalic Acid (TPA) has been widely used experimentally and in large scale field trials where its use has proven highly practical. The fact that it is not approved in the United States does not stem from any toxicity considerations, but rather a failure to submit the required data for clearance under the New Drugs, Food Additive, and other Regulatory requirements. Under U. S. requirements, one must show more attention to the efficacy and the safety of the considerations and interaction of any new additive with other conventional feed additives, both from a standpoint of efficacy, toxicity and tissue residue. Naturally, this requires a rather detailed and expensive testing. In the case of TPA, where its use has proved practical and economical under the existing price structure for TPA and broad-spectrum antibiotics, these exacting and expensive requirements have not been completed and submitted in the U. S. I believe, in Canada, however, the government has approved on the basis of data submitted on the use of TPA with OTC for treatment of broilers.

3. By — T. Runnels, U. S. A.

Could you comment on your feelings regarding the practicability of the use of potentiated antibiotics in coccidiosis in poultry? This is a very important area of commercial interest.

This area has been one of laboratory studies as it offers a convenient experimental tool for information obtained on both clinical effect and the antibiotics' blood level picture. In our studies we have been evaluating antibiotic potentiation using coccidiosis as a disease condition, employing mortality, lesion score, extent of bloody droppings and feed response as clinical criteria, and have simultaneously observed antibiotic blood level. In our studies using OTC and CTC against *E. necatrix* and *E. tenella* have shown the same type antibiotic blood response described in this paper, and a definite correlation between blood picture and clinical response have been obtained.

We find that potentiation can be measured by both clinical response and antibiotic blood levels in the same trial.

As to the testing, precaution must naturally be exercised in extrapolating laboratory data to what may be expected to occur in natural exposure in the field. In this regard, the degree of challenge and time of testing are important. We feel meaningful laboratory data should be obtained under sufficiently rigorous challenge conditions that significant mortality occurs in the unprotected groups, and that the tests should be run for sufficient time to give maximum translatability.

In our studies under these controlled conditions, we find that both OTC and CTC are effective against serious challenge of chickens



with both *E. tenella* and *E. necatrix* when fed at about 200 to 300 ppm under potentiated conditions. When these antibiotics are fed under unpotentiated conditions, up to 2 to 3 times higher levels may be required. Naturally, a large number of different strains found in the field should be tested before these findings can be considered as reduced to practice.

Naturally, cost of treatment is a governing factor in commercial coccidiosis medication. There are a number of effective coccidiostats presently available at a relatively low cost. This more effective use of antibiotics under potentiated conditions is a possible new factor. However, in coccidiosis therapy more work under commercial and academic conditions will undoubtedly be conducted in this area. It seems, however, that when potentiated antibiotics at adequate levels are fed for treatment of other diseases in poultry, that we may well be obtaining favorable effect on any coccidiosis that may be present.

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## DISCUSSION

MODERATOR. Thank you very much, Dr. Luther, for your suggestive paper and for your most brilliant exposition.

*Dr. Castella* (Spain). Regarding calcium, I would like Dr. Luther to indicate something about the influence due to the different qualification given the antibiotic if we would utilize a calcic, potassic, sodic penicillin, or a penicillin binded to other complete chemical groups.

*Dr. Luther* (U. S.). We have used pencillin types that are less soluble than sodic and potassic penicillin; however, these types have a great value from the practical point of view, because they make for greater stability in the feeds. Also, these substances, added in low levels to the feeds are equally effective than the more soluble ones.

*Dr. Castella* (Spain). Regarding the use of renal elimination reducers in conjunction with antibiotics, added to feeds for therapeutical purposes, do they offer any possibilities?

*Dr. Luther* (U. S.). As I have indicated, this is basically an economic type of investigation. Low calcium levels at given times, as determined by the



technician are the practice commonly followed in the United States. The utilization of terephthalic acid to reduce renal elimination is very important, inasmuch as it duplicates antibiotic effect.

*Dr. Castella* (Spain). Antibiotic utilization in animal feeds being a subject that is also related to costs, do you think it would be interesting to delay its absorption by adding another substance, for example, as it has been done with sulfamides, in order to reduce its cost?

*Dr. Luther* (U. S.). Yes, I think it would be quite interesting. It could represent an improvement system for antibiotic administration to use them in conjunction with other pharmacological products, for improved efficiency. We have already done some testing in this direction when researching on antibiotic potentiation.

*Dr. Runnels* (U. S.). Tetracycline used for disease control is highly useful because of its low toxicity level: however, do you have any information regarding the use of this antibiotic for control of coccidiosis in poultry?

*Dr. Luther* (U. S.). Because of its wide spectrum tetracycline has a very efficient action over coccidiosis, but its high price makes its use all but impossible, other products being used for this same purpose. However, with potentiated antibiotics we could, instead of giving 20 grams per ton of feed, control coccidiosis with a lower level of antibiotic.

*Dr. Cid* (Spain). First of all, I congratulate Dr. Luther, whom I had already the pleasure of listening during the III Week of Animal Nutrition Studies, at Santander, because of his most interesting lecture. However, I would like to remark—regarding the utilization of antibiotics in coccidiosis control—that in the practical level we have not been able to observe any advantages or improvements in efficiency on other products commonly used. Of course, by using potentiated antibiotics, and lowering their cost, this concept will probably change. Of course, the cost factor will have the last word in the fight against coccidiosis.

MODERATOR. I think there are no more questions regarding this subject. Now, Dr. Huber will talk on the subject «Tranquilizers and Sedatives».

## TRANQUILIZATION AND SEDATION FOR DOMESTIC ANIMALS

W. G. HUBER

Assoc. Prof. Vet. Medicine, University of Illinois U. S. A.

Only recently has psychopharmacology become an accepted branch of science. It is a science concerned with the psychological or behavioral effects of drugs. In its infancy it struggled with anecdotal or literary terms supplemented by anthropomorphic inferences from observations on animals. Psychopharmacology has progressed to a science that obtains its information by quantitative and objective methods which seeks to give a systematic account of the effects of drugs on objectively appraised behavior.



Behavior is the result of past and present environmental influences operating on an animal which has a complex but (for the individual animal) a fixed array of hereditary abilities and propensities (1). A science of behavior can thus be developed entirely in terms of events environmental to the animal. The introduction of drugs thus adds another factor that may possibly produce a change in behavior.

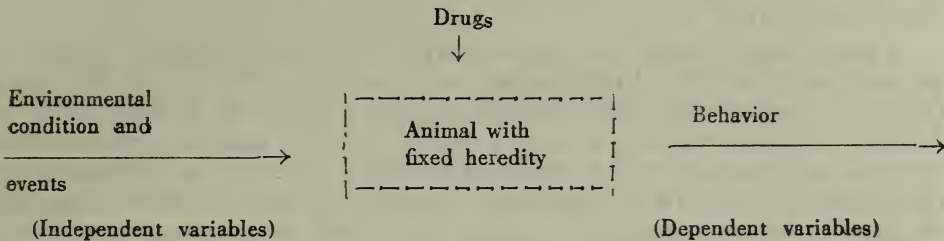


FIGURE 1.—Factors influencing behavior.

The environmental conditions and events which determine behavior must do so by causing physicochemical changes in the animal. Similarly, drugs which affect behavior must also act through physicochemical mechanisms.

Tranquilization and sedation are terms which describe behavioral conditions imposed on animals by the administration of certain drugs.

Sedative and hypnotic drugs produce a lesser degree of depression of the central nervous system than that which would result in unconsciousness as produced by a general anesthetic. A hypnotic drug induces sufficient depression of cerebral activity so that the animal becomes less aware of its environment and conditions favorable to sleep are established. Hypnosis differs from general anesthesia only in the degree of cerebral depression, hypnotic drugs being capable of producing all the characteristics of general anesthesia if given in sufficiently large doses. Sedation implies less profound activity than hypnosis and is the result of an elevation of the threshold of central nervous system irritability and of a lesser degree than that required to produce sleep. The difference between sedative action and hypnotic action is merely quantitative, since sedative drugs (eg. bromide, chloral hydrate, barbiturates) also have the capacity to produce loss of consciousness and even death as a consequence of central depression if very large doses are administered.

Tranquilization, in contrast to sedation and hypnosis, is achieved with a minimum of drowsiness and disturbance of mental activity. In general tranquilizing drugs act on the subcortical areas of the brain. One group (eg. phenothiazine derivatives and the Rauwolfia alkaloids) act primarily upon the hypothalamus and reticular areas. The other group (eg. meprobamate) acts mainly on the thalamus (2).

Chemically, the tranquilizing drugs fall within four general classes (3):

1. Those which contain the phenothiazine nucleus (eg. chlorpromazine, promazine, perphenazine).
2. Rauwolfia alkaloids (eg. reserpine, deserpidine, and rescinnamine).
3. Derivatives of alkyl diols (eg. meprobamate).
4. Derivatives of diphenylmethane (eg. hydroxyzine).

The Rauwolfia alkaloids contain an indole nucleus and are chemically related to serotonin (5 hydroxytryptamine), a central catechol amine.

It is obvious that the groups of tranquilizing compounds have little in common as far as chemical constitution is concerned. Their common denominator is their ability to produce certain effects in human beings and animals. After treatment people report that they are «relaxed» or «tranquil». Wild animals may become docile and easy to handle after receiving a tranquilizing drug.

Tranquilizing drugs may serve varied purposes depending upon their proposed achievement. Veterinarians desire a drug, which in addition to producing a calming effect, will actually produce sedation or assuage pain. For inducing chemical restraint a drug is desired that will decrease normal reflexes and accomplish a degree of sedation which will permit safe handling of excited or nervous animals. In contrast, in the practice of human medicine tranquilizers are used to relieve mental anxiety and are not used to assuage pain or produce a marked degree of sedation. They act chiefly to allay emotional tension without reducing conditioned reflexes.

The animal nutritionist has also become involved in using tranquilizing drugs at a greatly reduced level as feed additives. He hopes to accomplish two objectives when using a tranquilizing drug: 1. increase in daily gain and, 2. increase feed efficiency. The discovery of a growth-promoting effect of the tranquilizer hydroxyzine was made accidentally when graded oral doses of tranquilizing drugs were tested to quantify sedative activity (4). In ruminants it was noted that a growth stimulus was provided by extremely low levels, far below those that might produce sedation.

Hale has reported on 21 feeding trials involving 3,671 cattle, fed hydroxyzine at 2.5 mg per head per day (5). In cattle he observed that the average daily gain was increased 8.1 per cent or 0.2 pounds and feed efficiency increased by 7.4 per cent. Carcass grade and dressing percentage of animals fed hydroxyzine did not appreciably differ from those of controls. Hale also reported an additive action of hydroxyzine with other growth stimulants such as oral or implanted stilbesterol or oral oxytetracycline. In summarizing the growth studies with sheep fed hydroxyzine at 2.5 mg per head per day, a 10 per cent improvement in rate of gain and a 7 per cent increase in feed efficiency was reported. Additive action with other growth stimulants used in sheep was also reported.

Reserpine has been used experimentally as a feed additive in turkey and chicken rations. It is known that reserpine releases bound serotonin in the brain which is subsequently destroyed by monoamine oxidase and by this action it reduces blood pressure. The reduction of blood pressure by any anti-hypertensive agent such as reserpine has been reported to reduce losses incurred by the aortic rupture condition in turkeys (6). The effect that tranquilizers have on increasing gain and feed efficiency of poultry has been inconclusive. Burger *et al.* (7) reported a slight increase in growth in White Leghorn chicks fed chlorpromazine (10-100 mg/kg of diet), usually with decreased variability by the twenty-fourth day of age whereas with New Hampshire chicks growth was not affected. Higher levels of chlorpromazine (250-16,000 mg/kg of diet) depressed growth, and at 16,000 mg/kg produce 100 per cent mortality by the twenty-fourth day of age. They reported that reserpine when fed to White Leghorn chicks (0.5 mg/kg of diet) produced a



slight increase in gain whereas higher levels (5.0-500.0 mg/kg of diet) depressed growth, and at 500.0 mg/kg produced 96 per cent mortality by the twenty-fourth day of age. Drye *et al.* (8) reported that reserpine did not appear to have any effect on growth, feed consumption, mortality or behavior. They used graded levels up to 25 mg of reserpine per kilogram of diet.

Various tranquilizing drugs have been experimentally added to rations of dairy cattle and swine. In general no beneficial results have been observed in milk production, gain or feed efficiency.

Tranquilizers are applied mainly in two ways by veterinarians. One is to induce a quieting effect or to impose chemical restraint for physical manipulations. The other is facilitating environmental adjustment, eg., weaned calves moved to a new location.

A great deal of variation has been observed in similar animals treated with the same dosage level of the same tranquilizer. One animal may become docile and tractable after treatment; whereas another may become unduly excited. In general, if one uses the tranquilizing drugs discriminately and with the knowledge of undesirable reactions, then they are a very useful group of drugs to induce chemical restraint or to calm a nervous animal.

A number of suggested uses have been brought to the attention of veterinarians and livestock men involving injectable tranquilizers. These suggested uses included tranquilization of cattle to reduce shrinkage associated with loading, unloading and transport, reduce bruising and injury incurred in connection with transit, reduce shipping fever, and facilitate adjustment of calves to feed lot conditions.

Benefits derived from use of injectable tranquilizers in beef cattle have frequently been offset by the added handling time and expense necessitated by restraint of cattle in order to administer the injection. If a suitable tranquilizer could be administered in the drinking water or feed this time and expense would be obviated.

On occasions, cattle tranquilized before shipment to packing plants developed sizable necrotic areas at the injection site. Pounds of flesh had to be trimmed from the carcass to remove the damaged tissues, and carcasses were downgraded (9).

Carefully and well-designed experimental trials indicated that commercially available tranquilizers were of little or no benefit in reducing shrinkage and more than once they increased shrinkage in cattle during transit to feed lots or to slaughter houses (10) (11) (12) (13).

In a trial conducted by the Ohio Agricultural Experiment Station involving 180 feeder calves, shrinkage in tranquilized calves was 9.3 per cent whereas in untreated calves it was 9.1 per cent (14). Huber reported on the effect perphenazine had on the shrinkage of cattle and hogs during transportation by truck (13). The experiments were conducted as three-phase crossovers to eliminate animal to animal variation. In shrink evaluation much variation exists because of animal to animal differences in fill (ingesta and urine), weighing methods and proper handling of controls. The injection of perphenazine did not exert a beneficial effect in reducing shrink in cattle or hogs during or after transportation. To the contrary, perphenazine treated cattle showed a significant retardation of recovery of gain at 48 and 96 hours after transport and this was significant at the 0.1 per cent level. Similarly in swine so treated there was a retardation in the recovery of gain 24 hours after



transport. In this work an experimental tranquilizer, an imidazoline compound, was tested and found to exert a beneficial effect.

The incidence of shipping fever generally has not been reduced by use of injectable tranquilizers. The problem of evaluating the effect of tranquilizers on shipping fever is further complicated when one considers the paucity of information regarding transmission and etiology. However, the negative results that have been reported are of value in determining the efficiency of tranquilizing drugs. According to one investigator who conducted experiments on 180 cattle, the incidence of shipping fever was slightly greater in tranquilized cattle than in control cattle (14). Others have reported similar results with injectable tranquilizers in shipping fever trials (15) (16).

Mass use of tranquilizers has been found, on occasion, to be beneficial in certain aspects of beef cattle practice. They have been helpful in reducing fence-walking and bawling in newly weaned calves and have facilitated feed lot adjustments (14) (15).

In summary: 1. the tranquilizing drugs have been very useful in imposing chemical restraint; 2. commercially available tranquilizers have been disappointing in their ability to reduce transit shrink, bruising, etc.; 3. of the tranquilizers used as feed additives for nutritional purposes, hydroxyzine has been reported by many investigators to have a beneficial effect on daily gain and feed efficiency of domestic ruminants.

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## DISCUSSION

*Dr. Castella* (Spain). I congratulate the speaker on his very interesting paper. I would like the speaker to tell us whether the negative results may be considered as such because they are really negative, or just because there are not enough evidence of tests performed on dairy cows?

*Dr. Huber* (U. S.). In general lines, it is necessary to make more extensive research on this subject, because of the diversity of their chemical characteristics. More specifically, I should say that we have not as yet made much use of tranquilizers on dairy cows.

*Dr. Castella* (Spain). Regarding the use of tranquilizers for laying hens, could this occasionate an inhibition of reflexes basic for laying or, for meat poultry, Pavlov conditioned reflex?

*Dr. Huber* (U. S.). I have already stated that the results of tranquilizers are not yet too safe nor definitive. It would be necessary to study whether there exists a reduction in feed consumption, or feed efficiency with sedative utilization: whether tranquilizers reduce appetite at given levels, whether they can be of help in preventing the animals from getting scared of noise.

*Dr. Castella* (Spain). Inasmuch as we in Spain, as well as France and Portugal may have to face a serious problem regarding the use of tranquilizers on feeds intended for fighting bulls, for the unlawful purpose of reducing their fighting spirit, we would appreciate a discussion on analytical methods and detection of substances both in the animals fed such products.

*Dr. Huber* (U. S.). With some animals, such as cows and horses, the use of tranquilizers, while very useful, should not be trusted too much, because sometimes these substances have a toxic effect which excites them instead.

MODERATOR. This very important question can be related to what we call in France the «doping» problem, in race horses. Tranquilizers sometimes excite them, instead of having a sedative effect.



## PANEL II

*Dr. Cuenca* (Spain). The Moderator appointed for the present Panel, Dr. I. L. Mason, Scotland, does not need any introduction, inasmuch as his relevant personality is well known to all of us. I am sure that he will perform this task in a wonderful way, and we will do our best to make our questions as brief and clear as possible. Dr. Mason, please.

### ✓ SOME RECENT DEVELOPMENTS IN ANIMAL BREEDING AND GENETICS ✕

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At first sight it may seem strange to have a section on animal breeding at a nutrition conference. On second thoughts it appears as a very desirable arrangement. With increasing specialisation the old science of animal production (or zootechny) is splitting up and nutrition and genetics are now separate disciplines. At the same time specialisation of farming enterprise and industrialisation of some of them (e. g. poultry) mean that there is developing a demand for strains of animal for particular conditions, or feed-stuffs designed for special strains. To achieve these ends the geneticist and nutrition expert must come together again. Therefore I welcome this opportunity to present some ideas on animal breeding and genetics to an audience of nutritionists.

The history of animal breeding is very long; that of genetics is very short and only recently have the two had much impact on each other. Let us first consider animal breeding.

From the time when the various species were first domesticated some 7-8000 years ago, their appearance and productivity have been changed out of all recognition. Attention was directed first to external form; the plasticity of biological material in the hands of man is nowhere better exhibited than in the multifarious forms of the domestic dog all developed from a single original species. Cattle and sheep have been changed less but even within these species there is a startling variation in size, horns and local adipose accumulations. Above all the sheep has been given a fleece and the dairy cow an udder of size and productivity unknown in any wild form.

During the last few hundred years the possibilities of controlled breeding and the emphasis on productivity have accelerated the improvement in economic



characters and the resulting improved breeds give evidence of the phenomenal success achieved by the animal breeder without any help from the science of genetics.

The successful breeders, however, were few and most of the increase in productivity of cattle, sheep and pigs has arisen by the spread of genes from the successful herds throughout a breed followed by the spread of the improved breed at the expense of others. In this way the Shorthorn became dominant in Britain in the 19th century and also spread to many other countries. Now it is the turn of the Dutch Friesian; and territories as different as Siberia and Hawaii are discovering that the best way to improve milk yield is to import Friesian cattle.

Merino sheep, developed in Spain by some unknown benefactor of mankind, have improved or replaced sheep breeds over the whole world. The Large White and now the Danis Landrace pig have had almost as much impact on the pig population. This is the stage on which the geneticist has made his appearance. The history of livestock genetics during the present century may be conveniently divided into three phases. During the first twenty years after the rediscovery of Mendel's laws in 1900 attempts were made to apply his theory of inheritance to farm animals. The mode of transmission of such characters as colour and horns and of some abnormalities and lethal conditions, such as bulldog calves, was satisfactorily explained. This was of considerable interest to pedigree breeders anxious to fix their breed type. However, when Mendelism was applied to characters of economic importance like growth rate, milk yield, egg production, and so on, difficulties were encountered. Colour and horns are simple qualitative characters usually controlled by single gene pairs, but quantitative characters could not be fitted into such a simple picture. Attempts to explain the variation in milk yield by three segregating gene pairs (von Patow) or egg production by eight pairs (Hays) were hopeless failures.

The problem was solved almost simultaneously by the British statistician Sir Ronald Fisher, and the American geneticist Dr. Sewall Wright. They showed during the years 1918-21 that the variation in quantitative characters could be investigated by statistical methods. The assumption that these characters are controlled by Mendelising genes whose individual effects and locations cannot be identified, led to experimentally verifiable predictions. The emphasis turned from the genes to the characters they control. But the genetic control is combined with an influence from the environment and the relative magnitude of the genetic environmental components is one of the most important parameters in quantitative genetics. It is termed the heritability and is defined as the ratio of genetic to phenotypic variance or the proportion of the parents' superiority (or inferiority) in a given character which can, on average, be transmitted to the offspring. The heritability of a character in a population can be estimated from the resemblance between relatives and can then be used to predict future advances by selection.

Another important parameter is the genetic correlation between two characters. To take an example, there is a small negative genetic correlation between milk yield and butterfat test so that if we select for milk yield there will be a tendency for test to decline. Usually, as in this case, economic interest demands simultaneous selection for two or more characters. Knowing the heritabilities, genetic correlations, and the relative economic values of the

traits, theory can predict the best way to combine several characters in a selection index.

It is to Dr. J. L. Lush that we owe, to a very large extent, the application of the theory of quantitative genetics to farm animals. His influence has been spread far afield by the streams of papers, books (1) and pupils which have come out of Ames, Iowa. In Europe two of the first countries to be influenced by him were Norway and Sweden and in Dr. Berge from Oslo and Dr. Venge from Stockholm we are fortunate to have representations on this symposium from these two countries.

For the last ten years I would suggest that we have been struggling into the third phase of livestock genetics—the use of theory in the practical improvement of commercial animals. The theoretical work still continues and multiplies, and experimental work on laboratory animals (especially mice and *Drosophila*) continues to test the theoretical predictions. But while the genetic principles are the same for mice and cattle the genetic parameters (heritability, genetic variance, repeatability, genetic correlations, etc.) differ in magnitude. Therefore, sooner or later, investigation must turn to the economic animals themselves.

Even when we are using farm animals the question may arise whether results obtained at research institutes or experimental farms can be applied to ordinary commercial farms. It has, for instance, been amply demonstrated (2) that the results of the Danish Bull Progeny Testing Stations are not adequately repeatable under ordinary field conditions. In general terms we are asking if there is any genotype/environment interaction which will mean that breeding animals selected under one set of conditions will not be the best for use under another set. When the pedigree breeder is sharply separated in geographical location or standard of husbandry from the user of his stock this is a most important question and one to which I should like to return later.

For accurate estimates of heritabilities and genetic correlations large numbers of animals are needed. In the case of cattle very often more than a single experimental farm can carry. If the requisite records are available we can turn to the farmers' own stock for our research material. It is from this source that most of our knowledge of the genetics of milk production has come and it does have this advantage—the information comes from the same herds as those to which the conclusions will be applied.

But the major difficulties in applying to livestock improvement the recent advances in genetics are of an entirely different order. They arise from difficulties in defining the character or characters in which improvement is desirable, from religious tabus, from government policies (*e. g.* on self-sufficiency) or legislation (*e. g.* on sire licensing), from poor liaison between research and advisory services, from ingrained traditions about the importance of breed type or the relation between conformation and production, from superstitions concerning inbreeding and crossbreeding, and above all, from the natural caution and conservatism of farmers and breeders.

I would like to give some examples of current improvement schemes and how they are overcoming these difficulties.

Later speakers will be talking about pigs and about ruminants in the U. S. A. Therefore, I will, as far as possible, select my examples from cattle and sheep and from outside America.



## DAIRY CATTLE

For the dairyman the important thing about a cow is that she should be an economic producer of a large quantity of milk. The milk should have fat and solids-not-fat contents in accord with local legislation, taste or market requirements. Milk yield is easy to measure. Its heritability is not high but high enough to respond to selection. The bull cannot be tested directly so he must be evaluated by a progeny test. The difficulties lie in choosing the exact method of measuring milk yield and in the organisation of the progeny test.

Contributions from many research workers have led to fairly general agreement that the best measure of production is milk or fat yield in the first lactation truncated at ten or less months.

The organisation of the progeny test is more difficult. A major recent advance has been the demonstration that the differences between herd average milk yields are predominantly due to environmental factors—feeding, management, physical conditions—and not to differences in the genotypes of the cattle (3). Thus if the situation is one bull—one herd, it is impossible to evaluate the bulls, because bull differences cannot be separated from herd differences.

Fortunately, the widespread use of artificial insemination (A. I.) has solved this problem by putting daughters by several bulls simultaneously into a series of herds. All comparisons can be made within herds and the little bits of information from all the herds must then be combined into a single figure. In Britain this is done in a bull index called the Contemporary Comparison. It was developed by my colleague, Dr. Alan Robertson (4), and represents the difference between the yield of a bull's daughters and that of daughters of other bulls milking in the same herd in the same year.

The spread of A. I.—66 % of cows in England and Wales are now inseminated artificially—has also solved the problem of selling the method to the farmers. Instead of having to persuade each individual breeder of the merits of this system, it was necessary to persuade only the Milk Marketing Board which not only owns 23 out of the 27 A. I. centres in England and Wales but also runs the milk recording organisation and processes the records. Contemporary Comparison are now calculated automatically for all bulls with sufficient daughters in milk and, together with considerations of bull fertility and heifers' type (especially udder and hind legs), are used in the selection of all dairy bulls for A. I.

This system is working well. Its most recent justification came, again from Dr. Robertson (5) who showed that bulls with high Contemporary Comparisons were, as expected, producing sons whose daughters' milk yields are above average.

Its merits are appreciated in many other countries and it is gradually replacing the old equal-parent index and daughter-dam comparison. Scotland, Ireland, Israel and Australia have accepted the method *in toto*. In New Zealand and Sweden a similar scheme has been developed independently.

In England, however, opposition comes from some of the pedigree bull breeders. They have already suffered a reduction in the demand for bulls as the natural consequence of A. I. Now they see the Milk Marketing Board asking them to produce bulls tailor-made to its requirements and they feel



that their «traditional» function is being usurped. They would like to see more emphasis on breed type, cow families and other concepts which are of little interest to the commercial milk producer.

So much for the slow but steady improvement by selection within a breed. Even if all the emphasis were on yield alone and the progeny testing system were used to maximum efficiency, increase in yield would not exceed a rate of 1-2 % per annum (6). Are there no short cuts?

One suggestion is hybrid vigour. Several current experiments in U. S. A. and Great Britain are testing the possibility of increasing milk yield or butter-fat percentage by breed crosses. The results are not consistent but even when there has been an increase over the parental means, in no case has the better parental breed been exceeded. This method of breeding will probably not be a commercial proposition until selection has reached a plateau at a similar height in two unrelated breeds. Then we can expect a bump in yield on crossing them.

Research on blood characters might conceivably have practical application. A few associations have been found between specific blood groups and butter-fat test and also between serum globulin type and milk yield (7). However, although of statistical significance, the relationships are too slight to be of any economic importance. Personally, I do not think that there is much future in this approach. The effects of any single gene on milk yield are so small that progress will always be more rapid by selecting animals according to their yield (controlled by many genes) rather than by selecting a single gene even if it is known to have a slight positive effect. The interest of blood groups lies in their utility for paternity tests and in the indications they give concerning breed history and breed relationships.

## BEEF CATTLE

The difficulties in the way of improving beef cattle lie very largely in deciding what is the desirable character to select. Do we want large, rapidly-growing animals producing a lot of lean meat economically? Or do we want a small slow-growing, early maturing type, producing high-quality but expensive meat?

Selection in Scotland and U. S. A. has tended to produce breeds of the latter type — the Scotch Shorthorn, Aberdeen-Angus and American Hereford. On the other hand, such breeds as the Charollais in France and the Romagnola and Chianina in Italy are large and fast-growing.

On the basis of a bull performance test we can select bulls on growth rate — and this appears to be closely related to size. But we cannot tell much about the carcass by studying the conformation of the live animal. Until X-rays, radioisotopes, ultrasonics or dilution techniques can be used to determine the meat characteristics in the breeding bull himself, we must follow up the performance test with a progeny test. Only thus can we select the bulls which are producing offspring with the most desirable carcasses — low bone content, the right amount of fat in the right places, and meat which is tasty, juicy and, above all, tender. Current experiments in America are testing a scheme which would eliminate the progeny test with its long delay. Semen is drawn from selected performance-tested bulls and stored in a deep-freeze

for use after the bulls have been slaughtered. Selection can then be made on the basis of the bull's own carcass qualities.

But still the question remains, can we get both rapid growth and early maturity (i. e. fattening at an early age)? So far we have little evidence. The beef industry does not have a recording system analogous to the one which has supplied so much material on the genetics of milk production. We must wait for the slow accumulation of data from experiment stations. In order to add my contribution, I am organising beef progeny tests of A. I. bulls on semi-commercial farms (Agricultural Colleges, Farm Institutes and farms of feedstuff firms — B. O. C. M., Silcock, Spillers). So far, about 50 bulls have been tested or have progeny still on test.

Since the bulls concerned are all of a dual-purpose breed, it will be possible to calculate from these data genetic correlations between beef characters and milk production. This may not be of great interest in America where the beef and dairy industries are quite separate. Here in Europe, however, the majority of our cattle are dual-purpose (or even triple-purpose) and beef comes in large part from the same breeds (or their crosses) that are used for milk production and/or for draft. In England it is of fundamental importance to know what will happen to beef production when our main breeds (Friesian, Dairy Shorthorn and Ayrshire) are selected intensively for milk yield. The preliminary results from my study indicate that any effect will be small and that it will probably favour the larger, more rapidly growing type as against the early-maturing, beef type. In other words we can expect more meat of lower quality.

Short cuts in beef cattle breeding seem slightly more likely than for dairy cattle. There is, however, no indication that blood grouping will be useful. There is also no future in the production and crossing of inbred lines on the hybrid maize model — the formation of inbred lines of cattle is too slow and too difficult. Crossbreeding for beef production is common in many countries and is, in part, justified on the grounds of hybrid vigour. Although the evidence from British breeds is slight, I have recently seen most impressive results in Queensland (8) and in Texas (9) from crossing British beef breeds with the Zebu (Brahman). In both of these sub-tropical areas the growth rate (especially up to weaning) of the first cross is well above both parental breeds and it appears that fertility is also improved. I think there is a great future for such breeding systems in many hot, dry, pastoral areas of the world — including the Mediterranean.

Another interesting development in Queensland is the demonstration that sleek-coated cattle grow more rapidly and are more fertile than those with longer or woolly coats (8). This gives a criterion for selection which can be applied early in life. It would be interesting to know how true this is in more temperate climates.

## SHEEP

The most extensive work on the genetics of wool production is being carried out in Australia. Strains of Merino from many parts of the world were, in the last century, combined and selected to create the Australian Merino. Until recently, selection was entirely by eye appraisal, but it has produced a remarkable increase in fleece weight and quality. The scientist is now taking



a hand. Fleece weight has been analysed into a series of components — staple length, fibre diameter, fibre number per unit area, body surface area and degree of skin wrinkling—and the heritabilities and genetic correlations estimated for fleece weight and each component. Then, and most importantly, a series of lines were started in each of which selection is for a single character only. The exciting thing is that (with one exception) the correlated responses of the other characters have been exactly as predicted from the genetic correlations. For instance, there is a high negative correlation between number of fibres and fibre diameter; as expected, selection for increase in fibre diameter reduced fibre density and vice versa.

Selection for fleece weight was effective chiefly by increasing fibre number and staple length — both desirable characters in themselves (8). On the basis of all this information, a scheme for improvement in fleece weight has been worked out which is easily applicable to stud flocks (10). Fleeces are weighed at shearing and the first selection is made on greasy fleece weight. The heaviest fleeces are scoured and a second selection is based on clean fleece weight. Then a sample is taken and in a final selection the animals whose high fleece weight is due to coarse fibres are discarded. (Wrinkled animals will have been culled at an earlier stage.)

This is a very good example of the way systematic genetic study can be used to refine a traditional selection method. Its practical application is facilitated by the large size of flocks in Australia and depends on the presence of a sufficient number of progressive breeders who are prepared to break away from the tradition of «wool classing» by eye and hand.

Blood research has advanced less far with sheep than with cattle but one interesting development is worth recording. Sheep can be classified according to the potassium/sodium ratio in their erythrocytes. This ratio is inherited in a simple Mendelian manner, low potassium (J K) being dominant to high potassium (HK). In British breeds the frequency of the HK gene varies between 5 and 80 %, being higher in the hill breeds (11). In the Australian Merino the HK gene is virtually absent and a recent study on a small sample has shown the same for the Sardinian breed (12). Work in Australia indicates that the presence of the LK gene is associated with adaptation to a dry environment. It would be most interesting to discover if this characteristic is shared by the Spanish breeds.

## GENOTYPE/ENVIRONMENT INTERACTION

I would like to return now to the question of genotype/environment interaction. With milk yield it does not seem to be a problem. At least in small countries like Britain and Denmark, bulls tested in well-managed, high-yielding herds rank in the same order of merit when used in poorer herds (13, 14).

The same does not necessarily hold good for other characters and for larger environmental differences. The interaction between genotype and nutrition is a subject of peculiar interest to this conference and one about which we know little. Dr. Falconer in Edinburgh has tackled the problem by selecting mice for growth rate on two different planes of nutrition (15).



Both strains responded and naturally the mice fed *ad lib.* grew bigger than those on the restricted rations. When the rations were interchanged, however, the situation was completely reversed. The strain selected on a low plane did very well on the high plane but the pampered mice responded badly to a cut in rations. It appears that the high plane mice were being selected for appetite and the low plane mice for efficiency. Similar results have been obtained with pigs in U. S. A. (16).

Falconer's conclusion is that it is advisable to subject animals during selection to environmental conditions corresponding to the worst of the range under which the improved strain will be required to perform. When later transferred to better conditions they will grow as well and, if they are like his mice, will produce less fat carcasses than those on high plane throughout. The moral, in other words, is to keep your breeding stock on low commons and save the concentrates for feeding to your growing and fattening stock.

This experiment was concerned only with differences in plane of nutrition. It did not tackle the equally important question of the effects of qualitative difference in diets. This is a matter of some concern in Britain in connection with the introduction of bull performance testing. By testing bulls on feed lot shall we pick out those animals whose progeny will grow best on pasture? As yet there is no good evidence of genotype/environmental interaction in this case but it is a matter needing much further investigation.

To conclude, I would like to suggest that it is on the genetics of feed efficiency, feeding behaviour, and growth patterns and the interactions between genotype and feeding regime that we most urgently need research at the present time.

Now, I beg Dr. Bergeto read his paper, after which, Dr. Venge will read his. Both speakers will talk about «Genetics and Swine Breeding in Europe», and discuss the influence of the Lush school on the developments of the genetics and breeding of swine and ruminants in the United States. Dr. Lush himself will also speak about this subject, followed by Dr. Cuenca, who will speak about «Sheep Improvement».

## RECENT TRENDS AND DEVELOPMENTS IN GENETICS AND ANIMAL BREEDING IN EUROPE. SWINE

BY

S. BERGE

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The trends and developments in the pig breeding of Northern Europe in recent years are clear and easy to detect. From a practical standpoint the work proceeds in two directions simultaneously.

1. Improvement of the carcass to make it more in accordance with consumers' wishes. In recent years these have tended towards leaner meat and less fat.
2. Improvements aiming at reducing costs of production by breeding pigs with a higher rate of gain and lower feed consumption.

These two directions have to be given equal attention in the improvement of pig breeding.

### SELECTION METHODS IN USE TODAY

There will always be some discussion on which breeding method will give the improvements desired in the shortest time.

An approved method is: *The Danish progeny testing system.*

This type of progeny testing was initiated in Denmark already in 1899 and has gradually spread to other countries. It has gained most ground in Denmark, where it is the main cause of the high standard of quality obtained in Danish pig breeds. The system consists in selecting 4 pigs (2 sows and 2 boars) from a litter in which it is desired to test hereditary characters of the parents. At a weight of 17-18 kg, these 4 pigs are sent to a special station, where are fed according to a definite plan with regard to the composition as well as to the quantity of the fodder. After having gone through a preliminary period, the pigs are placed in experiment at 20 kg of live weight, and fed at the station until each has reached a weight of about 90 kg, at which time they are slaughtered. The carcasses are weighed, measured, and scored. The average results of the group are taken as an expression of the hereditary characters of the parents. When it is a question of scoring a male for breeding value, there will of course have to be more groups from the same male, out of different dams.

As soon as a group is finished, the results are distributed among the breeders, who can make use of them in the selection of breeding animals. A survey of the system has been given by KING (1955).



Countries using this system have in some cases reduced the number of pigs in each group to 2 only. This is doubtlessly justified from a purely statistical point of view. By using 2 pigs, a sow and a boar, in each group, it is possible to test a larger number of males at the same station. As an argument for using 4 animals, however, it can be mentioned that by choosing 2 sows and 2 boars from each litter, with a maximum difference in weight of 4 kg between them, and a mean weight of 17 kg, there will be less chance of selecting extreme animals. If only 2 were selected, they would probably often belong to the extremely good animals, and would not represent the litter.

This old and well-known method of selecting breeding animals from sibs and other relatives of the tested animals, is still recognized as effective, but its effect decreases with diminishing hereditary variation within breeds.

## RECENT IMPROVEMENTS OF SELECTION

In scoring characters in swine we find the paradox that a correct recording of the characters is first possible when the animals have been slaughtered, and the chances of using them for breeding purposes are lost. Experiments aiming at measuring carcass traits in live animals are in progress. Among the traits measured on *live animals* are back fat thickness and cross sections of the eye muscle.

*Back fat thickness.* It has been sought to measure this character on live animals by a number of methods. Among these are:

*Radiography.* This method is difficult. It also involves danger, and requires expensive apparatuses. It is hardly usable in practice.

*The rule method* consists in cutting through the back fat with a special knife, at the point of measurements, and inserting a graduated rule through the wound, down to the muscle *Longissimus dorsi*. The back fat thickness is then read from the rule. This method is not easy to use, and will hardly be practised generally. There is probably danger of infection. The method is not likely to involve much pain if the knife is sufficiently sharp.

*The lean-meter method* consists in inserting a needle through the back fat and reading the thickness of the back fat from the difference in electric conductivity between meat and fat. This method is less severe than cutting. According to the trials carried out at my institute, however, the error of measurement is too great when the method is used for animals with relatively little variation, as is often the case when bacon pigs of approximately the same size are concerned.

None of the above methods of measurement on live animals are expected to be of much practical value.

*The supersonic waves method*, based on the fathometer principle, has contributed greatly to the development of the measuring methods. It consists in recording the time elapsing before the supersonic waves meet obstacles.

The supersonic waves method has been used in testing of material since 1952, and has proved indispensable. The first approach to experiments on measurements on live animals was made by the English Pig Marketing Board, which in 1954 asked the manufacturers if the apparatus could be used for measuring back fat thickness in pigs. In 1956, experiments on measurement of fat layers in cattle were reported from U. S. A., and in November, 1956, the Frenchman DUMONT demonstrated in Jouy en Josas measurements of back fat thickness in pigs to members of a European Study Commission. In Germany the method was adopted by LAUPRECHT and KLIESCH.

The apparatus was changed by LAUPRECHT and his coworkers in Mariensee so that it became more suitable for measurements on live animals.

*The supersonic waves method* has in recent years been tried in several countries. Of the literature on this method we can mention KLIESCH and coworkers (1957), who found a close agreement between back fat thickness, measured by means of supersonic waves, and that obtained through control measurements of the carcass. They found the least deviation on back and hips, where it was  $\pm 5$  per cent only. The greatest deviation was found in the neck, where it amounted to as much as 25 per cent. The supersonic waves method was investigated at my institute by SKJERVOLD and coworkers (1960), who took measurements of a total of 709 animals at 90 kg of live weight.

Some of the animals were measured at 50 kg also. Of this material 320 animals were measured alive, and the rest as carcasses. On the assumption that the direct measurements on the carcasses are free from error, the error of measurement of the back fat by supersonic waves was  $\pm 1.46$  mm, which corresponds to 4.5 per cent of the mean thickness. Thus the error does not exceed the limit permitted. A greater difficulty arises by the fact that the supersonic waves measurements give somewhat less back fat thickness than the real measurements. A correction can be made for this, and corrections of the measurements should in fact be carried out for both age and live weight, if the measurements are to be applied during growth to compare the back fat thickness with that considered desirable.

It should also be noted that back fat thickness and total amount of fat are highly dependent on feeding level and feed composition. A small deviation from the feeding level will easily result in misleading values.

In Germany the supersonic waves method has also been used to measure the cross section of the eye muscle, *Longissimus dorsi*, and to measure the thickness of the back fat. The measurements are taken at the 13th rib, along a line following the curvature of the side, at a right angle to the direction of the spinal column. The location of the 13th rib is determined according to estimate. From 13 to 16 measurements, 1 cm apart, were taken from the highest point of the back and down the sides. At each measurement the following dividing lines were recorded: skin, first dividing line in fat, lower limit of fat, and upper and lower limit of *Longissimus dorsi*. The values obtained from the reading were used to plot a figure of the outlines of both fat and muscle. A description of this method has been given by DIEKMANN (1960) who maintains that the technique can be improved, perhaps by photographic recording of the border areas. However, even in its present form the method offers great advantages by enabling a direct selection, based on the



carcass quality of live animals, instead of a selection necessitating slaughtering the animals in order to establish their principal traits.

It is fairly obvious that the results of the measurements depend entirely on the feeding and care of the pigs. It is easy to produce pigs with thin back fat by underfeeding them.

To make the above method usable the animals have to be fed *ad lib.* on a comparatively concentrated feed ration. The actual error of measurement is a secondary consideration.

Another important advance made in swine breeding in recent years results from the technical progress made in artificial insemination. Only a few years ago the results obtained by artificial insemination in pig breeding were so poor that there was little justification for adopting this method in practical breeding. With the modern methods developed in England and other countries, Norway among others, the rate of fertility has become so high that the method is recommendable under many conditions.

As a result of this, a more methodic testing of the males can be carried out. In Norway a selection system has been worked out on this basis. The system is outlined below.

## PRINCIPLES OF SELECTION IN PIG BREEDING

Pig breeding in Scandinavia is chiefly based on the Danish system of progeny testing, and until a few years ago, no alternatives to the Danish system had been tried.

In Norway, artificial insemination in pig breeding came into general use in 1956. This year, there are four A. I. stations in operation, and 15 to 20 per cent of the sows are inseminated. The extensive use of A. I. in pig breeding is chiefly due to the small size of the pig herds in Norway—they usually comprise from 3 to 5 sows. As a consequence of this the price of mating per sow is relatively high. Also, the rate of conception is now higher for artificial insemination. Last year the non-return rate was between 65 and 70 per cent.

Artificial insemination opens up great possibilities of improving swine genetically. The advantages to be gained in pig breeding are considerably higher than those obtained in cattle. The chief advantages are:

1. The progeny testing. This is the cornerstone of selection, and it can be made more exact than in natural service, because the number of offspring from each boar is considerably larger.
2. The selection can be more intensive, as the selection interval, i. e. the difference between the selected boars and the average of boars, can be much greater.

At the ordinary pig testing stations today, it is necessary to slaughter the pig in order to carry out the tests. The records from pig testing stations can be used in two different ways:

1. As progeny tests for selection between the parents of the tested animals.

2. As a sib test for selecting full sibs and half sibs of the tested animals.

If the performance test could be carried out without slaughtering the animal a third type of selection would be possible, since we could select the performance-tested animal for breeding.

In pig breeding today boars have primarily been selected on the basis of tests of their offspring only. The repeatability of this testing will of necessity be low. There are several reasons for this, namely:

1. Progeny tests in such cases comprise a relatively small number of offspring, and the number of dams for each progeny group is usually small in comparison with the number of offspring.
2. All progeny come ordinarily from *one herd only*, and the culling based on the individual's own merit within the sow material varies from herd to herd.
3. Sows served by each individual boar are often interrelated and the higher the coefficient of relationship within the dam groups, the lower the repeatability of the progeny test.
4. There is generally a systematic difference between herds with respect to the feeding of young pigs prior to their being sent to the testing station.

The causes mentioned under 2, 3, and 4, lead to a systematic difference between progeny groups, which is not founded upon hereditary differences among sires. In addition to this comes the fact that the pig breeding herds do not have several tested boars at *the same time*, and breeders are thus prevented from carrying out culling the progeny-tested boards in any great measure.

By changing to artificial insemination, a reduction of the systematic error between progeny groups is possible, and the repeatability (accuracy) of the progeny testing will be increased. Further, artificial insemination will make it possible to effect an *intensive* selection among the progeny-tested boars.

To the extent it is possible, the selection has to be based on a *combination* of mass selection (based on performance test), and family selection (sib test, progeny test, and pedigree).

## SELECTION BASED ON ARTIFICIAL INSEMINATION AND PERFORMANCE, COMBINED WITH PROGENY TESTING

A special selection scheme has been worked out at my institute for artificial insemination in swine breeding.

A brief description of the scheme is given in the following:

Progeny from young A. I. boars and dams in commercial herds are collected for progeny testing of the boars. In each group of progeny there are 2 pigs, each from 14 litters (28 pigs from each sire).



Under Norwegian conditions this is the optimum size of a progeny group, a conclusion based on careful calculation.

When the pigs to be tested have to be transferred to special testing stations, the optimum number of offspring per group of progeny will depend on the heritability, the intensity of selection of the progeny-tested boars, and the resources (money, housing) available.

For ranking of the tested boars, a selection index based on litter size and test of offspring, is used, in which the relative weights of the different traits are as follows:

|                    |       |
|--------------------|-------|
| Litter size        | 16 %  |
| Feed efficiency    | 40 %  |
| Rate of gain       | 10 %  |
| Back fat thickness | 13 %  |
| Length of carcass  | 5 %   |
| Carcass score      | 6 %   |
| Conformation score | 10 %  |
|                    | <hr/> |
|                    | 100 % |

The best of the boars are used in A. I. both in elite herds and commercial herds.

## HOW TO SELECT BOARS FOR PROGENY TESTING

The effect of the progeny testing system depends largely on how boars intended for progeny testing have been selected. A preliminary test of young boars is based on the following scheme:

The best boar out of four progeny-tested boars is selected for insemination of elite sows to produce A. I. boars to be used in the next generation. The elite sows are selected by an index, and inseminated with semen from the specially selected progeny-tested boars. The «best-looking boar» from each of these litters is given a performance test at a special testing station, where economy of gain, rate of gain from to 20 to 90 kg live weight, and back fat thickness, measured by supersonic waves, are recorded. Finally, each boar is scored for conformation.

Four sibs belonging to the litter from which the young boars have been selected, are sent to the testing station. Here, in addition to feed efficiency and rate of gain, data from the carcass examination are recorded and used in the evaluation of the young boars.

The young boars are ranked by the selection index, where emphasis is placed on both performance test and sib test. The best *quarter* of the tested young boars go to the artificial insemination stations.

Of course, a greater improvement could have been achieved if it had been possible to test so many young boars that one-fifth or one-tenth would have been enough to meet the requirements of the A. I. stations, but this would increase the costs, especially of the sib test, and might in some cases reduce the total effect.

Sufficient data for an exact calculation of the optimum number of young

boars tested are not available as yet. The suggested optimum is not far from the best one-fourth, i. e. the total number of young boars tested are four times the number of boars required at A. I. stations.

\* \* \*

This selection system has been in operation only a short time and it has not been possible to compare it with the old system, but it is hoped that it will give a more rapid improvement, even if it has to be improved in some ways. The question of the quality and quantity of the feed at the test stations will always give rise to differences of opinion and differences in the systems employed by the different tests stations, will render comparisons between the boars invalid.

## SUMMARY

In order to improve the quality of pigs and to get a more economical pig production, a special plan for selection of boars has been started in Norway.

The system presupposes the use of artificial insemination and facilities for measuring some of the carcass traits on live animals.

The system requires: 1) Testing stations for offspring of A. I. boars; 2) Testing stations for young boars; 3) A stock of elite herds of shows (about one out of 300 herds).

The selection of boars is made in two steps:

1. Selection between boars used at A. I. stations and in elite herds.
2. Selection of boars for use at A. I. stations and in elite herds.

Boars at the A. I. stations are used for inseminating sows in commercial herds and elite herds, and offspring from both types of herds are sent to the testing stations for fattening. When the pigs are slaughtered and the average results calculated, the boars with the best offspring are used for inseminating the sows of the elite herds.

The best male offspring from these litters are sent to the testing stations for young boars, where growth rate, conformation, etc., are recorded and back fat thickness is measured on live animals. The number of young boars at the testing stations are at least four times that required at A. I. stations. When sexual maturity has been reached, the best of the boars are sent to the A. I. stations for general service.

If a quarter of the young boars are selected for the A. I. stations and a quarter of the A. I. boars are used in the production of the next generation of young boars, the selection per generation will be the best boar out of 16 tested boars.

The system, which constitutes a very intensive exploitation of the hereditary variation found in the breed, will in a short time reduce the hereditary variation to almost zero, except for some types of interaction.

To get a continuous improvement the possibility of increasing the hereditary variation (heritability) should always be kept in mind.



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## GENETICS AND SWINE BREEDING IN EUROPE

BY

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Since the beginning of the 20th century there has been an enormous increase in Europe in the production of meat from swine, especially in the Scandinavian countries. In England a number of different breeds was developed during the eighteenth and nineteenth century, but on the continent most breeds, if they should be defined as special breeds at that time (60-70 years ago), belonged to a local landrace which was characterized by slow growth, low weight and, at maturity, a relatively thick layer of backfat. In many countries the use of imported boars and sows from England involved an improvement of the local landraces, but in other parts of Europe, no or only little improvement has taken place during the last 50-60 years. The breeding was and still is more or less planless in many parts of Europe, while in the more developed countries, the application of the theories of modern population genetics is growing rapidly. In such countries the breeders usually are organized in associations, which are responsible for pig recording, pedigreeing and progeny testing etc. It should, however, lead too far in the discussion to go into details concerning the organization of pig breeding, and those who are interested are referred to the review by CLAUSEN and GERWIG (1958): Pig breeding recording and progeny testing in European countries. (FAO Agric. Studies, n° 44).

## I. BREEDING POLICY IN THE BEGINNING OF THE IMPROVEMENT-PERIOD

*As an example of how the breeding was practised during the first part of a period which could be called the improvement-period, the development of the pig industry in Denmark can be used.* From a production of meat pigs with a rather thick backfat for marketing in Germany in the years about 1880-1890, the production was changed into bacon pigs which would fulfil the demands of the English market. With this change a period with crossbreeding started. A rather large number of pigs, especially of the «Large White» breed but also Tamworth, was imported and used for crosses with the native landrace. The cross breeding was subsidized, e. g. by slaughterhouses and Government, and on the shows the crossbred animals got the highest prices. However, although it was clear that the crossbred animals were more uniform than Landrace offspring, many farmers were not satisfied with the «Large White» gilts and sows as mothers, and preferred to improve the Landrace itself (VENGE, 1944).

From a genetic point of view it is interesting to see how the breeding during the nineteenth's developed as a pure breeding with «Large White» and the old «Landrace» and a crossbreeding (reciprocal) for production of market pigs.

Although nothing was known about Mendelian inheritance the farmers were warned against the use of  $F_1$ -animals as breeding individuals.

In order to get more rapid progress a certain number of recognized herds was founded. In 1895 4 such herds were established for «Large White», and the year after the first came for «Landrace». In 1900 the number of recognized herds was 91 for «Landrace» against 15 for «Large White». In the recognized herds the owner pedigreed his animals, but the relationship between animals from different herds was in general unknown. In order to avoid «inbreeding» it was then proposed to establish a «pedigree» register or herdbook comprising «pure bred animals». This was accomplished in 1906.

Another characteristic feature in the development of a rational pig breeding in Denmark was the foundation of the progeny testing stations. Without the present-day knowledge of the fundamentals of the genetics of quantitative characters it was soon realized, that the best way to estimate, what to day is called «breeding value» (in the meaning of additively genetic value), was the examination of the progeny. The progeny testing of boars and sows in Denmark was started in 1907.

During the following years the scheduled programmes were followed up, with purebreeding in two breeds combined with a mass selection for the most economical traits for a bacon pig, and some crossbreeding between the pure breeds for production of market pigs. In many cases, however, the  $F_1$ -animals were backcrossed to «Landrace» if a farmer found the  $F_1$  better than his pure bred breeding stock. In this way valuable genes from the «Large White» has been *introduced* into the Danish «Landrace».

In the years up to about 1930, it was common to have the 3 types on the progeny testing stations, and from a study of these data it can be seen that



the crossbreds generally, with regard to food conversion rate, length of carcass, daily gains and thickness of fat, show intermediate inheritance, or as it was called in earlier days, «blending inheritance». In later years the use of «Large White» has decreased in Denmark.

In some other European countries the breeding has developed in about the same lines as in *Denmark*, but it must be pointed out that in many countries the market demand is for a heavier pig than the bacon pig or a breed which is suitable for pork. These things can influence the breeding policy. In some other parts of Europe one can hardly speak of an organized swine breeding, and that means that difficulties arise in adopting the modern theories of population genetics for improving the stock in the wanted direction. I will come back to this later.

## II. BREEDING AND SELECTION METHODS

As already mentioned, the pure breeding has been the leading principle in the development of the Danish Landrace, and so it has also been in most other European countries. In all parts of Europe, however, some crossbreeding occurs and has been used for the improvement of several breeds. But within a pure breed different breeding methods have been used. The most common is a breeding based on selection and pairing unrelated animals. On the other hand, cases of close inbreeding, e. g. brother-sister, or parent-offspring, can be found in improved as well as in primitive breeds. The reason for using inbreeding is often difficult to find out. In many cases it seems as if it happens by mistake, in other cases it seems as if the breeder has had difficulties in finding animals good enough to use to his own, and he therefore takes the chance to mate related animals. In no cases systematic inbreeding seems to have been practised; the only exception being inbreeding experiments carried out on experimental farms (e. g. HALLQUIST, 1932, KING and ROBERTS, 1959).

Despite the fact that in Denmark no advantage was found in crossbreeding between Landrace and Large White, this cross is still in use in other countries with a well developed swine breeding. In Sweden e. g., the cross is very common and experiments are in progress for a study of an alternating cross between Swedish Landrace and Large White. In the experiment reciprocal crosses are used. The preliminary results indicate less variation in the  $F_1$  animals. In this case it is possible to study the variance within the group crossbred, while the results from the earlier crossbred progeny groups in Denmark do not allow this, as no individual data are published in the reports. A few data from the Swedish crossbreeding experiment are presented in table 1 (SKÅRMAN, 1960).

The reason for the increasing interest in crossbreeding with swine is probably due to two causes. Firstly, the extended use in U. S. A. of crossbreeding between different lines and/or breeds, influenced by the poultry and maize industries, in order to utilize heterosis. SECONDLY, the fear of inbreeding followed by a general decrease in viability, fertility and perhaps other economic traits. But also the feeling that further progress seems difficult to achieve, i. e. that certain breeds should have reached a plateau, which is impossible to pass. Against these arguments it must be emphasized, that in most European breeds,

TABLE I

RESULTS FROM A CROSSBREEDING EXPERIMENT WITH SWEDISH LANDRACE  
AND LARGE WHITE (YORKSHIRE). (AFTER SKARMAN, 1960)

| Character                    | Number      | Combinati6n |       |       |       | Significans of difference |       |
|------------------------------|-------------|-------------|-------|-------|-------|---------------------------|-------|
| MEAN VALUES:                 |             | LL          | YY    | LY    | YL    | LL-LY                     | YY-YL |
| Number of pigs at birth      | 160 litters | 10.7        | 10.2  | 10.8  | 10.8  | none                      | none  |
| Number of pigs at 8 weeks    | 160 litters | 8.5         | 7.4   | 9.0   | 7.9   | none                      | none  |
| Birth weight, kg             | 1702 pigs   | 1.47        | 1.34  | 1.52  | 1.40  | 0.50*                     | 0.05  |
| Weight at weaning, kg        | 1308 pigs   | 14.89       | 13.53 | 15.36 | 15.28 | none                      | 0.001 |
| MEAN SQUARES:                |             |             |       |       |       |                           |       |
| Number of pigs at birth      | 160 litters | 10.67       | 14.36 | 6.69  | 13.90 | none                      | none  |
| Number of pigs at 8 weeks    | 160 litters | 6.36        | 9.19  | 5.57  | 5.79  | none                      | none  |
| Birth weight                 | 1688 pigs   | 0.06        | 0.06  | 0.07  | 0.06  | none                      | none  |
| Weight at 8 weeks            | 1308 pigs   | 9.08        | 10.97 | 7.85  | 7.78  | none                      | 0.05  |
| MEAN VALUES:                 |             |             |       |       |       |                           |       |
| a) <i>Restricted feeding</i> |             |             |       |       |       |                           |       |
| Age at slaughter, days       | 858 pigs    | 205.7       | 204.3 | 196.8 | 198.5 | 0.001                     | 0.01  |
| Daily gain, grammes          | 858 pigs    | 514         | 529   | 545   | 539   | 0.001                     | none  |
| Feed units per kg gain       | 858 pigs    | 3.14        | 3.00  | 2.96  | 3.02  | 0.05                      | none  |
| Thickness of backfat, cm     | 854 pigs    | 3.08        | 3.01  | 3.06  | 2.98  | none                      | none  |
| b) <i>Ad libitum feeding</i> |             |             |       |       |       |                           |       |
| Age at slaughter, days       | 312 pigs    | 176.4       | 169.0 | 170.9 | 172.9 | 0.05                      | none  |
| Daily gain, grammes          | 312 pigs    | 622         | 661   | 644   | 639   | 0.05                      | none  |
| Thickness of backfat, cm     | 310 pigs    | 3.29        | 3.30  | 3.28  | 3.18  | none                      | none  |

LL = Landrace, YY = Large White, LY = Landrace ♀ x Large White ♂,  
YL = Large White ♀; x Landrace ♂;

\* Refers to  $P < 0.05$ ,  $P < 0.01$ ,  $P < 0.001$ .



there is still a lot of genetic variability available for further progress. Concerning the change in the variation for certain characters during the last 30 years reference is made to table 2. In addition, there is an important difference in the swine breeding policy between the old and the new world. In European countries with a well organized swine breeding programme the breeding is performed on restricted feeding, in contrast to what is common in U. S. A. Furthermore, the registered breeds in U. S. A. are mostly lard-type breeds (about 90 %) while in a number of European countries the aim is the production of bacon.

TABLE II

CHANGE IN MEANS AND COEFFICIENTS OF VARIATION (C. V.) FOR TWO MEASURABLE TRAITS AND ONE SCORE-TRAIT FOR DANISH LANDRACE (AFTER CLAUSEN AND NORTOFT THOMSEN, 1960)

| Year     | Length of carcass |          | Thickness of backfat |          | Score for bacon type |          |
|----------|-------------------|----------|----------------------|----------|----------------------|----------|
|          | Mean, cm          | C. V., % | Mean, cm             | C. V., % | Mean score           | C. V., % |
| 19 26/27 | 88.88             | 3.00     | 4.03                 | 10.94    | 12.17                | 7.57     |
| 19 36/37 | 92.81             | 2.53     | 3.48                 | 11.15    | 12.53                | 8.15     |
| 19 46/47 | 93.39             | 2.23     | 3.33                 | 9.94     | 12.58                | 8.24     |
| 19 56/57 | 94.39             | 2.19     | 3.11                 | 10.13    | 12.75                | 9.02     |
| 19 58/59 | 95.09             | 2.14     | 2.96                 | 10.37    | 12.76                | 10.84    |

Concerning the risk for an increase in the coefficient of «inbreeding», it is difficult to say how large it is in the different breeds or sub-breeds used in Europe. For Swedish «Landrace» the average coefficient or «inbreeding» based on six generations has been calculated to 1,9 with a range for individual litters between 0 and 25,1 % (BRÄNNÄNG, 1956). These figures refer to 342 litters, born after boars which are registered in the herdbook of 1953. The corresponding figures for «Large White» in Sweden is 2,1 % with a range between 0 and 10,3. The coefficient of relationship for boars in the herdbook from 1953 was found to be 4.06 %, while the average coefficient or relationship between boars and gilts from other lines amounted to 3.1 %, the highest being 12.8 %, the lowest 1.3 %. For the elite of Danish Landrace, i. e. animals from the recognized herds, the coefficient of «inbreeding» has been found to be 11.5 % in 1959 (JONSSON, 1960), while in 1934 the coefficient of inbreeding for registered animals averaged 7.3 % (ROTTENSTEN, 1937). For the half sib group on the progeny testing station a coefficient of relationship of 0.295 was found instead of 0.25 (FREDEEN and JONSSON, 1957).

The reason for the increase in the coefficient of inbreeding seems to be due to the way in which the breeding is organized. No or only little attention has hitherto been put to basic principles in population genetics. The breeding is in many cases a breeding in closed herd. In Sweden for example it is almost impossible to have a boar tested if his father is not registered in the herdbook.

The rule for having a boar (or sow) progeny tested is in most countries, that the parents should be herdbook registered animals. This restriction will influence the selection of animals for breeding. In most European countries

the capacity of the testing stations is in general so low that only a small proportion of the boars (and sows) can be tested (cf. CLAUSEN and GERWIG, 1958). This means that the selection very often is done on type or conformation of living animals, using a score system, which is less effective than a progeny testing. However, the progeny testing will increase the interval between generations and thus lead to less improvement per year. In order to overcome these obstacles two ways can be followed. *In Denmark the breeding is still based on the progeny testing*, but this is open also for non-recognized herds. There are 3 progeny stations for the recognized herds and 16 local stations for non-recognized herds. The total capacity is a testing of 10-12.000 pigs a year, or about 2.500 groups. The other way is the use of the Iowa-system with a testing of boards (and sows) for daily gain food conversion rate and thickness of backfat before the animals are used for breeding. The system has aroused great interest in many European countries, especially in Germany and Norway, but also in other countries experiments are under way for studying the validity of the method.

The characters to be selected for are so to say the same in all European countries; with different weight of different characters depending upon the aim for the swine breeding. The most important characters are fertility, daily gain, food conversion rate, length of carcass, thickness of fat, and in the latest year the area of the eye muscle. A lot of different bacon characters are also included, e. g. firmness of fat, lean meat, colour of meat etc. From a genetical point of view it seems at first to be impossible to get improvement simultaneously for so many characters but fortunately there is a reasonably high genetic correlation between many of them. In table 3 some genetic correlation coefficients are shown, cited from the literature. Some phenotypic correlations are also given.

From the computation presented in the end of the table it is seen how important it is that genetic correlations are computed in the same way. The genetic correlations as well as phenotypic correlations between measurable traits are on the whole  $2\frac{1}{2}$  - 3 times as large if they are based on full sibs not litter mates compared to the correlation based on litter mates.

The meaning of genetic correlations (and heritabilities) must be seen in connection with selection and selection-indices. However, the use of selection-indices is not common. In Germany there seems to be great interest for constructing such indices, but it requires more knowledge about the heritability of the economic important characters as well as the phenotypic and genotypic correlations between the characters.



TABLE III

GENETIC CORRELATION BETWEEN DIFFERENT IMPORTANT TRAITS IN BACON PIGS

II. *Fredeen and Jonsson* (1958): Danish Landrace.

|                 | M a l e s |             |            | F e m a l e s |             |            |
|-----------------|-----------|-------------|------------|---------------|-------------|------------|
|                 | Length    | Feed Effic. | Daily Gain | Length        | Feed Effic. | Daily Gain |
| Feed Efficiency | — .178    |             |            | — .022        |             |            |
| Daily Gain      | + .086    | — .962      |            | + .079        | — .866      |            |
| Backfat         | — .471    | + .278      | — .186     | — .319        | + .164      | — .170     |

III. *Johansson and Korkman* (1950): Swedish Landrace.

| Different traits in full sibs:    | Litter mates |                     | Full sibs from different litters |                     |
|-----------------------------------|--------------|---------------------|----------------------------------|---------------------|
|                                   | d/f          | Genetic correlation | d/f                              | Genetic correlation |
| Thickness of backfat, cm (x) —    |              |                     |                                  |                     |
| thickness of belly, cm (y)        | 421          | —0.14               | 893                              | —0.45               |
| Length of carcass cm (x) —        |              |                     |                                  |                     |
| thickness of backfat, cm (y)      | 421          | —0.15               | 893                              | —0.42               |
| Length of carcass, cm (x) —       |              |                     |                                  |                     |
| thickness of belly, cm (y)        | 421          | 0.07                | 893                              | 0.20                |
| Thickness of backfat, cm (x) —    |              |                     |                                  |                     |
| firmness of fat, points (y)       | 349          | —0.21               | 749                              | —0.17               |
| Length of carcass, cm (x) —       |              |                     |                                  |                     |
| size and shape of ham, points (y) | 421          | —0.10               | 893                              | —0.09               |
| Length of carcass, cm (x) —       |              |                     |                                  |                     |
| firmness of fat, points (y)       | 349          | —0.11               | 749                              | —0.23               |
| Firmness of fat, points (x) —     |              |                     |                                  |                     |
| size and shape of ham (y)         | 349          | 0.23                | 749                              | 0.34                |
| Length of carcass, cm (x) —       |              |                     |                                  |                     |
| age at slaughter, days (y)        | 421          | —0.09               | 893                              | 0.10                |







### III. ESTIMATES OF HERITABILITY FOR DIFFERENT CHARACTERS

In the years after the second World War the interest for estimation of the heritability ( $h^2$ ) for different economic characters grew rapidly, and to-day many results have been presented. As is natural these results are based on data from the progeny testing stations and are thus applicable only for recognized herds or registered animals. Some examples will be presented in table 4. In addition some more detailed calculations were done on the thickness of fat and uniformity of the thickness; interested readers are referred to the original work by KING (1957).

In general there is a good agreement between the different estimates of heritability for the economic important traits. Concerning the heritability for fertility, it is in most cases found much lower than for the above mentioned traits, and as an example can be mentioned, that for German Improved «Land-race» it was found to be 0.14 and for German «Weideschwein» to 0.12 (LAUPRECHT and DÖRING, 1954).

TABLE IV

#### EXAMPLES OF HERITABILITIES OF SOME BACON TRAITS

##### I. *Fredeen and Jonsson* (1957): Danish Landrace.

|                      | Males |              | Females |              |
|----------------------|-------|--------------|---------|--------------|
|                      | $h^2$ | $\sigma h^2$ | $h^2$   | $\sigma h^2$ |
| Length               | 0.483 | 0.106        | 0.485   | 0.114        |
| Feed efficiency      | 0.720 | 0.114        | 0.451   | 0.112        |
| Daily gain           | 0.665 | 0.112        | 0.351   | 0.107        |
| Thickness of backfat | 0.516 | 0.115        | 0.576   | 0.115        |

##### II. *Jonsson* (1958): Danish Landrace.

|                            | $h^2$ | $\sigma h^2$ |
|----------------------------|-------|--------------|
| Thickness of backfat       | 0.711 | 0.0508       |
| Score for lean meat, uncut |       |              |
| bacon side                 | 0.675 | 0.0503       |
| cut bacon                  | 0.701 | 0.0507       |
| Percentage of bacon        | 0.439 | 0.0447       |



III. *Johansson and Korkman* (1950): Swedish Landrace.

|                       | $h^2$ |
|-----------------------|-------|
| Length of carcass     | 0.62  |
| Thickness of backfat  | 0.52  |
| Thickness of belly    | 0.40  |
| Firmness of fat       | 0.40  |
| Size and shape of ham | 0.61  |
| Daily gain in weight  | 0.26  |
| Age at slaughter      | 0.57  |

IV. *Osterhoff* (1956): German Improved Landrace.

|                             | $h^2$ |
|-----------------------------|-------|
| Length of carcass           | 0.52  |
| Thickness of backfat        | 0.46  |
| Thickness of belly (streak) | 0.16  |
| Age at slaughter            | 0.23  |
| Daily gain in weight        | 0.54  |

V. *King* (1957): Large White.

|                                                  | $h^2$ |
|--------------------------------------------------|-------|
| Carcass weight                                   | 0.30  |
| Weight of bacon                                  | 0.53  |
| Skin weight                                      | 0.38  |
| Width of body                                    | 0.47  |
| Depth of body                                    | 0.002 |
| Length of body                                   | 0.54  |
| Leg length                                       | 0.61  |
| Thickness of backfat<br>(average 3 measurements) | 0.46  |
| Thickness of belly<br>(average 3 measurements)   | 0.52  |
| Depth of eye muscle                              | 0.29  |

#### IV. OUTLOOK (THE SWINE BREEDING IN THE FUTURE)

In the efforts made to achieve as rapid an improvement as possible the best results have been obtained in countries where the selection of breeding animals is based on progeny testing. However, this does not mean that the system is allright, and that no change is necessary. From the very beginning of progeny testing it has been common to test 2 castrated boars and 2 gilts from the individual litters. Earlier theoretical speculations on the number of animals in a test-group has confirmed the number of 4 (LUSH, 1936). In the later years, however, the problem has been analyzed from a somewhat different angle, and it has been shown that a testing of a few more litters or groups with less number of animals within the group gives results which are just as reliable (or more) as a testing of 4 individuals from fewer litters (KING, 1955). Another problem which has been subject to theoretical speculations is the composition of the test litters. It has been shown that the testing of 2 males and 2 females reduces the genetic progress with about 10 % under conditions of short interval between generations (80 % of the gilts is used for breeding per generation), compared to e. g. 2 males and 1 female (FREEDEN, 1953). This is due to the reduction in selection-intensity. These considerations have not yet been applied in the European progeny testing stations with the exception of France. In Portugal the opposite sex combination is used, but this will under normal conditions not give less genetic gains per generation than the use of  $2 \sigma^7 + 2 \varphi$ .

Apart from the sex combination of the test litter, there is also a problem related to the total number of animals which should be «tested» every year. It was mentioned earlier that the capacity, for testing varies considerably between the different countries, but nothing was said about the need for progeny testing stations. In a recent communication from Edinburgh, this problem has been taken up to discussion by SMITH (1959). He demonstrates that the genetic gain is a function of the number tested (N) to the number required (T), so that the improvement is proportional to the *logarithm* of this

ratio  $\left(\frac{N}{T}\right)$ . If there are for example 1.000 pedigree breeders in a country,

which require the testing of 1 boar per year, and the testing capacity on a station is, say 400 pigs per year, the ratio  $\frac{N}{T}$  becomes  $\frac{400}{1000} = 0.4$  which

will give a rather small improvement because all herds can not get a boar tested. If on the other hand a nucleus system is built up with a rather few pedigree herds or recognized herds the genetic gain will increase due to a

much higher  $\frac{N}{T}$  ratio. If, for example, only 50 breeding herds are allowed

to use the progeny testing station the ratio would increase to  $\frac{400}{50} = 8$ , which

would give a genetic gain of more than three times as much. — How these considerations will be applied in practical breeding is impossible to say; to



some extent they are already in use in the countries with a well developed swine breeding, where the recognized herds in fact form a nucleus in the stock.

It can also be mentioned that there is a great interest for working out methods which make it possible to evaluate bacon traits on living animals, i. e. *the use and perhaps extension* of the IOWA-SYSTEM for boar testing, but it is too early to say anything about how this will work.

Finally it should be mentioned that the progeny testing also is in use in some countries for detecting lethals. How much weight whi should be laid on these tests, usually carried out as a father-daughter test, is still under discussion. The frequency of lethals is rather low and it is only a small percent of abnormalities which has a hereditary background.

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## RECENT TRENDS IN THE BREEDING OF SWINE AND RUMINANTS IN THE UNITED STATES

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First I will speak of trends that are somewhat general, in the sense that they apply importantly to two or more species; then about the developments which are largely confined to some one of the species or, at least, are of major importance only in that one; and finally about new things in breeding methods or genetic questions which seem likely to concern several species.

### GENERAL TRENDS

1. Productiveness per animal continues to increase for almost every character for which we have dependable data. These characters include such physiologically diverse ones as milk and fat production, egg production, economy of feed conversion, litter size in swine, fleece weight, and growth rates. In none of these do I see any sign that we are approaching a ceiling; indeed the *rate* of improvement seems to be increasing if it is changing at all. Presumably such ceilings do exist for some characters but all the evidence available now indicates that the time when those ceilings will hamper further improvement is still so many animal generations distant, that we need not worry about ceilings now. Our successors will have plenty of time to devise ways of circumventing them if and when that contingency does arise.

Presumably also, the remarkable improvement in the last four decades, especially in the last two and a half, is by no means all genetic. Improvements in nutrition, in management, in the effectiveness of veterinary measures, and in the control of parasites and pests have surely played a part. However, the effects of some of those have been partly cancelled by more intensive stocking and crowding and the resultant greater exposure to parasites, diseases, etc. If a dairyman now keeps 30 cows where his father kept 10 or 12 only 40 years ago, it is by no means certain that these modern discoveries have made the environment kinder to the individual cow, even though they have improved it from the standpoint of her owner!

Even in experimental data, we have no wholly satisfactory way for measuring absolute genetic trends, although various control devices do permit us to be reasonably sure of the direction and rate at which one stock is changing, as compared with another. In survey data, such as necessarily are the basis of figures on nation-wide trends in animal productiveness, no way of separating cleanly the genetic part of that trend from the environmentally-



caused part is yet available. I do not see that we would make much practical use of such a separation if we did have it, although I would dearly love to know, what really happened, just for my own mental satisfaction. As one of our poultry breeders said a few months ago: «I do not particularly care to measure the absolute genetic changes in my flock: what I do want desperately to know is how stock compares with the stock of my strongest competitor!»

2. Everywhere there is increased interest in measuring the individual productiveness of animals and in progeny testing. Measuring individual productivity is more advanced in some species, such as dairy cattle and chickens, than in others but the interest in the subject seems about equally lively among breeders of all kinds of animals. Through the 1920's and 1930's the geneticists wrote and exhorted about the merits of progeny testing. By now, the subject seems to have been oversold for some people. Articles and questions often imply that without the progeny test one can do nothing and with it he can do everything! In many ways this is a welcome change, but it makes necessary more emphasis now on keeping the breeding plan well-balanced; using mass selection as far as it is effective and yet will leave room for other forms of selection; sib-testing when and as much as is appropriate; progeny-testing on performance in a cross, where the product being marketed is a cross; progeny-testing within the line to correct mistakes made by the earlier methods; etc. Only a few of the females can be progeny-tested adequately and only a tiny fraction of the males. In many cases it may well be that the biggest part of the improvement which can be done in any one generation is that accomplished when deciding which males shall be tried for breeding in the first place.

3. Heterosis is being used more systematically and widely by producers of market products than ever before. This trend seems to be increasing. It has gone furthest in poultry where practically every major breeder is now marketing crosses for his customers to use in producing eggs or in growing broilers, but rotational cross-breeding is widely used in swine production and some are exploring the uses in such rotations, of stocks bred especially for cross-combining ability. Crossbreeding has always been used widely for producing market lambs but that use is increasing, if it is changing at all. Cattlemen are using crossbreeding only a little more than formerly but that use seems to be growing, perhaps as a result of the demonstration of the success of crossing in chickens and pigs. In the case of dairy cattle, the practical means for the widespread use of crossbreeding is at hand in the A. B. studs, for the dairyman who uses those, but such use seems not to exceed some 15 to 25 % of the inseminations.

## SWINE

The goal is now for more muscle and less fat in the carcass while yet retaining rapid gain and economical feed conversion. This is accomplished partly by marketing at lighter weights and partly by breeding. Self-feeding seems sure to remain the typical way of feeding pigs in the United States in the major pork-producing regions. There is no prospect of using limited feeding to attain leaner hogs at market weights and I am not aware of any profitable way of making the carcasses leaner by putting more fiber in the ration and yet continuing to self-feed.



Marketing at lighter weights increases the overhead costs of maintaining the breeding herd, per 100 kg. of live hogs marketed. This, along with more expensive buildings and equipment, has increased the interest in raising more pigs per sow per year. This is manifest in various ways, such as earlier weaning, having four farrowings per year (At least two groups of different sows are involved of course), as well as more strenuous efforts to breed for larger numbers farrowed and weaned per litter. All this is leading toward more specialization in the raising of pigs. The farmers who just raise a few litters as a minor part of their farm operations are producing a smaller fraction of the total pig crop than such farmers were 30 years ago although most farms which raise pigs do remain somewhat diversified in their farming interests.

Boar-testing stations must now number more than 30 or 40. Their procedures vary somewhat. A few come close to the standard Danish pattern of feeding two barrows and two gilts from the same litter. Many more follow some such pattern as feeding in each pen four pigs by the same boar but out of at least three different sows. Usually three of these are boars and one is a barrow. Only the barrow is killed for detailed information on his carcass, but the boars are probed for thickness of their back fat, when they approach market weight. Thus the boars themselves can be selected on their own performance for fast growth and yet thin back fat, and on feed conversion of a group of four, of which the boar himself is one and the other three are his half or full brothers, and on the other carcass details of a half or full brother. Theoretically this should give more rapid progress in improving growth rate but reducing fat (and therefore presumably selecting for more muscles), about the same progress in selecting for feed conversion, and a bit less progress in improving carcass qualities not included in growth rate and thinness of back fat than would the standard Danish system, although that depends much on the use actually made of the results. The results constitute a rather good progeny test of the sire, (except for details of carcass quality) although not of the dams. Often one or more sales of the boars which do best in these tests (usually about the best two thirds of them) is held at the end of the tests. This adds much to breeder interest and support.

True progeny tests according to the Danish model are rather rare, although some experimenting with this plan has been done here and there since 1926. The fact that in the United States the carcasses are sold as wholesale cuts, rather than as whole sides as is usual in the «bacon» market in Britain, perhaps has much to do with less emphasis being placed on carcass qualities. In making and trimming these wholesale cuts, a skillful man can repair with a knife some of the defects of carcass shape which could not be concealed if the carcasses were sold whole.

## DAIRY CATTLE

Artificial breeding is widespread and continues to grow. Its main appeal is economic, as is evidenced by the average size of the herd using it being only about eight cows. Its main genetic effect, so far, is the obvious one that it permits more intense selection of bulls, since fewer are needed. This of itself may have made the rate of genetic improvement about 1.3 to 1.4 times

what it would be with natural service, but it can hardly have made the rate 1.5 times as high. However, the selection of the bulls has gone out of the hands of the cow owners into the committees or other groups who select the bulls for the studs. Some increase in the average skill of those who actually choose bulls may have resulted thereby, but this is uncertain and hard to measure. Some of the studs are already laying tentative plans about what they can do to breed better bulls than they can now buy. This could become an interesting development, but is only in the pilot stage as yet.

The data from artificial breeding are already permitting some answers to questions which previously could only be asked. The major new kind of data (other than direct information on differences among the bulls in their own fertility) is that now paternal half sisters occur scattered almost at random through many herds, as well as in the same herd, and that contemporaries in the same herd often are by different sires. For instance, it now appears that the real differences between herd averages are mostly environmental, being caused only about 10 % (certainly not more than 20 %) by differences between those herds in their average breeding values.

The problem of how to get more cows tested remains. Among the heifers sired artificially, rarely are as many as 10 % of them in herds which are being tested. Thus many of the data which might be used for proving sires, or for locating the cows who ought to be dams of bulls, are never collected.

Central processing of the data from those herds which do test is spreading rapidly, as modern computing machinery becomes used more widely. The reports usually go back to the herdowner within a week after the tester was at his farm. Not only are fewer of the good cows and bulls overlooked, but the information comes back sooner. Often this makes the difference between the information actually being used and its merely being filed. More seems still to need doing to extract early from the part-lactations such useful information as they contain. Also records contemporaneous or adjacent to each other in time usually resemble each other somewhat because of changes in environment with time or because of carry-over effects. On some occasions this needs some discounting not now being done.

The content of milk in solids-not-fat is being investigated in many places with a view to being ready for appropriate action in case the market starts to pay for that, and breeding for more solids-not-fat become practical but, as far as I know, no action programs in this field have yet been started in the United States. The subject is still in the research stage.

Possible genetic partial antagonisms between two or more desired characters, such as (perhaps) milk production and meat production, and the effects of such possible antagonisms on selection indexes, goals, rates of progress, etc., are being investigated theoretically and the facts are being assembled for some pairs of characters but I do not know that any action, based on these theories or findings, has actually been taken. The general trend seems to be toward dairying and beef production both becoming more specialized in different directions, with the dual purpose cattle becoming less prominent in agriculture in the United States! I suppose that is more because of economic and advertising reasons than because of biological ones. Equipment costs are rising and as the increasing sanitary regulations are making more equipment necessary, the dairyman finds it necessary to keep more cows in order to hold down the



overhead costs per cow. A fairly common view dairyman is: «You must get bigger or get out.»

The problem of sterility, or at least of low reproductive rates, continues to absorb much attention and research. Its very complexity makes unlikely any sudden or extreme improvements in it but its high economic importance justifies much research. This problem is acute in beef cattle also but, due to the nature of the case, most of the research work is done with dairy cattle.

## BEEF CATTLE

Performance testing is getting much emphasis. Perhaps some 15 or 20 performance testing stations are operating. Some of these combine progeny-testing features by having several sons of the same sire entered. The techniques and the usefulness of these stations are still in the pilot stage. Because of the possibly large carry-over effects of pre-test environment, many think that most of the performance testing should be done on the home farm or ranch. But that offers no opportunity for comparing one's own stock with the stock of other breeders, nor for the advertising which a favorable result in such comparisons would bring.

The goals or ideals for beef cattle breeders are receiving more critical scrutiny than for many decades. The points most at issue are fatness and size. What has happened to lard in the markets has caused many to wonder whether a similar fate is ahead for tallow. Several consumer preference studies have shown that many customers when choosing among ready-to-cook slices actually avoid «prime» or «choice» steaks in favor of «good» or «standard» ones, even when the price difference is subsidized out of the picture for the purposes of the study. These findings have added to the uneasiness about whether we are aiming at the right goals and whether our grading systems really represent the general market or only the preferences of epicures who are only a small fraction of the consuming public.

Experience with «compact» or «comprest» or other «pony» types has caused many breeders and growers to turn back toward more size. The trend toward smaller cattle which has been almost continuous since before 1890, at least in the show rings and in the market topping commercial cattle, seems to have reversed although I see no prospect that it will go back to where it was before 1910.

These questions of goals enter into performance testing. The main qualities being emphasized in those tests are rate of gain, economy of feed conversion, and a bit of scoring or rating of market acceptability.

New «breeds» are numerous, specially in the southern half of the United States, where the breeds originating in north western Europe seem not as well adapted as they are in the northern half of the United States. Probably these crosses should not be called «breeds» until after they have had at least one generation of mating together cows and bulls which are alike in the percentage of blood which they have from the original cross. Only in the first generation thus produced will the heterosis caused by dominance have

disappeared entirely. However, the makers of these new «breeds» are understandably in a hurry to profit by any sales advantages which may be had by calling them «breeds». In some cases the combination of genes may be superior enough so that, even when the heterosis has disappeared, the resulting breed may still be superior to other groups of cattle.

## SHEEP

The major source of income to the sheep grower is shifting a bit more toward mutton and away from wool. This has been going on for a long time and, of course, varies with the region. In the rougher and more desert-like parts of the west, wool remains more important than mutton. Since most wool in the United States is of intermediate degrees of fineness, it has not yet felt the competition from synthetic fibers as keenly as have very fine wools, such as the best Australian ones. What the future holds in this respect should be foretold only by men who are both prophets and chemists!

Performance testing for greasy weight (and later for clean weight) of fleece has progressed so rapidly on some ranches in western states, where the Extension workers were alive to their opportunities (for example in New Mexico), that the wool yields of some commercial flocks have surpassed those of the purebred flocks. When and as this happens, the rancher has little real reason to buy purebred rams any longer and the situation is ripe for something approaching the system of flock registration which the breeders of Merinos in Australia have long used. If the commercial producers go in strongly for performance testing and the breeders of purebreds fritter away their time and their freedom to select, in paying attention to «fancy points», the stage is set for something like this to happen.

In sheep, probably more than in other species, breeds have waxed and waned in popularity. New breeds come to the fore and old breeds recede into the background and dwindle in numbers. Why? Is it that the breeders of pure breeds have been bewitched by non-essentials and gone chasing after will-of-the-wisps? Or is there some kind of intrinsic weakness in long-continued pure breeding? Or is there some other reason?

## BREEDING METHODS AND GENETIC QUESTIONS

Making well-balanced plans which will make the optimum use of mass selection, sib-testing, progeny-testing, etc., requires a quantitative approach and a sharper knowledge of some of the biological parameters of the problems than we yet have. It is also necessary to know well the requirements of time, lines and space in the actual operations of the breeder. In this field the work will never be done completely. Often a new device or a minor idea, of no considerable scientific importance, will pay big dividends in more efficient improvement.

The principles of making new breeds are becoming clearer, although the prospects of financial profit in such endeavors are still dim. Most important of these principles probably is the importance of keeping the genetic base broad enough so that the random genetic drift will not fix on the new stock,



before the breeder notices it, some undesired trait which can be corrected only by an outcross which would also undo nearly everything the breeder had accomplished with the new stock up to that time. Also a cross will often have some heterosis which will make it appear better in the early stages than it will be when it has finally been interbred long enough to have been really welded into a new breed. So far as heterosis is due to dominance and an excess of heterozygotes, the heterosis in a cross will not all disappear until the first generation produced by mating together males and females which have the same «percentage-of-blood» composition. Then, for the first time one can see what he really has from which to begin the work of improving the new breed.

In both sheep and pigs men have had considerable experience in making new breeds for several decades. Now this is being done often in cattle and rather frequently with light horses. Even if most such efforts fail, still a few successes are likely.

In practice, a breeder *must* pay attention to several things differing in importance and some of them interfering with each other at least a little. Selection indexes for making the rate improvement a maximum have been receiving increasing attention over the last 20 years. Their construction requires four kinds of information: (1) The relative economic value of a unit of improvement in each of the characters in which improvement is being sought; (2) heritability of each; (3) the genetic correlations; and (4) the phenotypic correlations between each pair of such characters. The first is just a way of defining the breeder's goal in terms which will permit balancing defects in one character and unusual merit in another quantitatively, so as to reach the proper decision about the animal's net merit, as is done verbally by all breeders and is approached quantitatively in their score cards. Information on the second is accumulating, although the confidence interval around most such estimates is wide and some estimates surely contain still undetected biases. Only a beginning has been made at measuring genetic correlations and the methods of estimation still have regrettably large sampling errors. Information on phenotypic correlations is rather abundant, except for characters which have only recently begun to receive attention. Selection indexes seem to help most; (1) where heritability is low; (2) where genetic partial antagonism (negative genetic correlations) exist; and (3) where reproductive rates and replacement rates prevent the selection from being really intense.

Finally, among the genetic questions we would like to have answered are those old friends: How important are epistatic differences, overdominance, and interactions between heredity and environment? These largely determine whether we should use heavily or only slightly such breeding plans as line-breeding, reciprocal recurrent selection, and how far we should go towards breeding separate varieties for separate special purposes or for special environmental niches.

## IMPLICATIONS FOR ANIMAL FEEDING

Increasing specialization in dairying and swine production, as well as in poultry production, seems to mean that more perfect feeds will be required for speeding up the animal processes, especially when the animals are left in confined quarters or other conditions quite unlike those under which their

ancestors have lived for centuries. However, most livestock producers will also be producers of feedstuffs and will continue to regard their animals as ways of marketing those advantageously. Some exceptions to this will occur of course, as in the broiler industry, but mostly livestock farming will be a way of utilizing best whatever natural resources are available, rather than a factory into which feed and other raw materials are brought to be transformed into animal products. The livestock producer will be wanting mostly feed supplements, rather than buying all of his feeds.

## SHEEP IMPROVEMENT

BY

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### I

#### PRODUCTION PROBLEMS IN SHEEP

The various world statistics relating to sheep do not coincide with each other; generally it may be noted that the tendency of increase among sheep is inferior to the growth of the world's human population:

| Years | Human Population |       | Sheep Population |       |
|-------|------------------|-------|------------------|-------|
|       | Millions         | Index | Millions         | Index |
| 1925  | 1,800            | 100   | 600              | 100   |
| 1958  | 2,655            | 148   | 750              | 125   |

The distribution, per continent, of sheep and humans is approximately as follows:



|           | Km <sup>2</sup> (1) | Inhabi-<br>ants (1) | Density<br>per km <sup>2</sup> | No of<br>sheep (1) | 0/<br>0 | No of<br>km <sup>2</sup> | heads per<br>1000 inhab. |
|-----------|---------------------|---------------------|--------------------------------|--------------------|---------|--------------------------|--------------------------|
| Europe    | 10.1                | 562.5               | 36                             | 182                | 24.3    | 18.2                     | 321                      |
| Asia      | 44.1                | 1505.3              | 34                             | 115                | 15.3    | 2.4                      | 76                       |
| Africa    | 30.2                | 216.8               | 7                              | 106                | 14.2    | 3.5                      | 490                      |
| America   | 42.2                | 355.9               | 9                              | 172                | 22.9    | 4.0                      | 485                      |
| Australia | 9.0                 | 14.8                | 1.6                            | 175                | 23.3    | 19.4                     | 11,824                   |
| TOTALS    | 135.5               | 2655.2              | 19                             | 750                | 100.0   | 5.5                      | 282                      |

(1) Millions.

The figures of the world's sheep population, as compared to those of all other species of domestic animals, and calculated in physical as well as in normal heads (1 normal head = 1 of cattle, 1 of mule, 1 of horse, 2 asses, 4 pigs, 10 sheep or goats, 100 hens) may be set out as follows:

|        | PHYSICAL HEADS |       | NORMAL HEADS |       |
|--------|----------------|-------|--------------|-------|
|        | millions       | %     | millions     | %     |
| Sheep  | 750            | 36.5  | 75           | 7.9   |
| Cattle | 650            | 31.7  | 650          | 68.4  |
| Swine  | 300            | 14.6  | 75           | 7.9   |
| Goats  | 200            | 9.8   | 20           | 2.2   |
| Horses | 90             | 4.6   | 90           | 9.4   |
| Mules  | 15             | 0.6   | 15           | 1.6   |
| Asses  | 44             | 2.2   | 22           | 2.6   |
| TOTALS | 2,049          | 100.0 | 947          | 100.0 |

Regarding the distribution of sheep per country, 90 % of the world population is reared in 31 countries, with at least 5 million head each:

| COUNTRIES             | Millions<br>of sheep | COUNTRIES       | Millions<br>of sheep |
|-----------------------|----------------------|-----------------|----------------------|
| 1. Australia          | 127                  | 17. Yugoslavia  | 12                   |
| 2. Argentine          | 55                   | 18. West Africa | 10                   |
| 3. Soviet Union       | 50                   | 19. Italy       | 10                   |
| 4. India              | 39                   | 20. Iran        | 10                   |
| 5. Union of S. Africa | 36                   | 21. China       | 10                   |
| 6. New Zealand        | 36                   | 22. Bulgaria    | 9                    |
| 7. United States      | 32                   | 23. Rumania     | 8                    |
| 8. Uruguay            | 26                   | 24. Greece      | 8                    |
| 9. Turkey             | 26                   | 25. France      | 7                    |
| 10. Spain             | 24                   | 26. Algiers     | 6                    |
| 11. England           | 23                   | 27. Chile       | 6                    |
| 12. Ethiopia          | 18                   | 28. Pakistan    | 6                    |
| 13. Brazil            | 16                   | 29. Sudan       | 6                    |
| 14. Peru              | 15                   | 30. Portugal    | 5                    |
| 15. Afghanistan       | 15                   | 31. Bolivia     | 5                    |
| 16. Morocco           | 14                   |                 |                      |
|                       |                      | TOTAL           | 670                  |

The countries underlined in the above table are those which have an important wool production: they produce enough for themselves, and besides they are able to export certain types of high quality wool, even though the total production may not be of a consistently high quality in some of the types of wool produced. (Turkey, Spain, Italy, Portugal, Algiers, France, etc.) In some of these countries sheep do also produce considerable quantities of meat. (England, France, New Zealand, Australia, Argentine, Uruguay and the United States.) Besides some countries which are not mentioned in the foregoing table are well-known for the high quality of their wool and for their extensive meat production (Germany, Holland, etc.).

Almost all the types of sheep reared at present proceed from two quite distinct stocks:

1. An original and very ancient stock of sheep with long, thick, straight wool, containing little oil and scaly corticals which are not very well developed, without medulla but with a tendency towards it (especially when feeding conditions are unsatisfactory), and with pigment both in the wool (medulla, cortical zone or both) and in the skin and visible mucous, evenly distributed or appearing in spots, conditioned by a great number of restricting factors in connection with the colour, which limit it to special parts of the body, or which obliterate it, so that in some cases the animal is totally white, although genetically possessing all the characteristics of colour. This type is constitutionally hyperthyroid and of a respiratory biotypology, with a straight profile. The majority of milk-sheep belong to this type of strain, being poorly adapted to the production of textile wool. In general they are not especially suitable for meatproduction, this being considered in its present day sense of meat of young, precocious animals, with a high coefficient in the utilization of food and of a high yield in meat categories.

2. Another original stock of sheep with short, fine, wavy wool, containing a considerable amount of oil and well developed cortical scales, is probably of more recent origin. The fibres lack medulla (true wool), and the restrictive colour factors in the wool, skin and visible mucous are more perfect than in the previous group, due to the continued process of selection carried out by man in his attempt to obtain purely white wool. Nevertheless there remains a genetic basis of colour, which may reappear at any moment. This type of sheep, essentially represented by fine-wooled merinos, shows certain constitutional and biotypological characteristics which prove to be contradictory. For example, in the profile there are corporal sections showing a rectilinear tendency (the nasal line), while others are clearly concave (rear extremities); the pronounced hyperthyroid disposition which permits the highly active functioning of the dermic system (wool follicle, sebaceous and sudoriferous glands), is confronted by a well-known low milk producing potentiality (this latter characteristic being proper to animals of a respiratory biotype) and by a marked disposition for the production of precocious meat in young animals (commonly found in a type which is clearly anabolic or digestive: French or English strains of a merino basis, with high meat production).

Both stocks have been developed side by side, with constant cross-breeding, the strains having been subject to a greater or lesser degree of genetic stabiliza-



tion and adaption to their environment. The characteristics of these cross-bred and medium-fine types are as follows:

a) They have a fleece with medium-fine wool, covering almost the entire body, with hair of a kind halfway between the square and closed (fine wool) of the Merino and the conical, sharp, open hair of the coarse wools.

b) They may produce associated yields: milk-wool-meat, milk-wool, meat-wool, depending to a great extent on the forage available.

Bearing in mind the great difficulties which had to be overcome in connection with genetic stabilization of these intermediary types, which is frequently at the mercy of the economic circumstances of the market, we must say that these genetic hybridations have been carried out in a masterly fashion in many countries, especially in Anglo-Saxon countries, giving rise to groups which today may be considered to be special breeds in their own right: Leicester stock, with all its derivations (Devon, Dorset), Corriedale, Columbia, Targhee, Polwarth, etc.), the French Ile-de-France stock, the German Mele, etc.

In other places, however, especially in the Mediterranean countries, hybridization or cross-breeding in the search for new strains, has been carried on, since time immemorial, in the most anarchical manner, in a zig-zag without plan, so that the result is a crossed population which is pronouncedly heterogenic.

In any case the cross-bred strains are fighting for supremacy with the traditional fine-wooled merino, due to the formers' greater hardiness, higher capacity for adaptation (although involving the risk of lower genetic constancy) and suitability for double or triple associated productions. Undoubtedly the need for fine wool, which is imperative, is filled by countries such as Australia, and to a lesser extent by New Zealand, Argentine, Uruguay, South Africa, Brazil, etc. But even in these countries (New Zealand, Argentine, South Africa, etc.) there has been a perceptible increase in double-purpose, medium-fine woolled (mainly, though not exclusively, Corriedale) or double-purpose, less fine-wooled sheep, with a high meat productivity (for example: Romney March). Also one may find there some definitely coarse woolled sheep of a very prolific, rustic breed suitable for double birth and meat production (for example: Dutch Texel). Besides, all types of fine wool suffer, whether they like it or not, from strong competition by synthetic fibres.

Following is an attempt to classify the different types of wool-producing sheep:

*Breeds producing fine wool.*—All these are derived from the Spanish Merino strain, which first appeared sometime between the 11th and 13th centuries, and which attained its greatest splendour in the period between the 15th and 18th centuries. Towards 1750 they began to spread throughout Europe, and subsequently to all parts of the world. Below we set out a tentative list of the present day merino types and those derived from the Spanish merino, either in its pure state, or cross-bred:

| CONTINENT AND BREED                          | MAIN APTITUDE  | PROCESS OF FORMATION |
|----------------------------------------------|----------------|----------------------|
| <b>EUROPE</b>                                |                |                      |
| <i>German Merinos:</i>                       |                |                      |
| Elector of Saxony                            | Very fine wool | Selection (1)        |
| Id. of Silesia, Prussia and Northern Germany | Very fine wool | Selection (1)        |
| Mele                                         | Wool and Meat  | Crossing (2)         |
| <i>Austrian Merinos:</i>                     |                |                      |
| Negrete                                      | Very fine wool | Selection (1)        |
| <i>French Merinos:</i>                       |                |                      |
| Rambouillet                                  | Fine wool      | Selection (1)        |
| Ile-de-France                                | Meat and wool  | Crossing (3)         |
| Precocious merino                            | Meat and wool  | Selection (4)        |
| <i>Italian Merinos:</i>                      |                |                      |
| Gentile di Puglia                            | Fine wool      | Crossing (4 bis)     |
| <b>AFRICA</b>                                |                |                      |
| South African merino                         | Very fine wool | Selection (5)        |
| <b>AMERICA</b>                               |                |                      |
| <i>North American Merinos:</i>               |                |                      |
| American Merino                              | Very fine wool | Selection (5, 10)    |
| American Rambouillet                         | Fine wool      | Selection (6)        |
| Columbia and Targhee                         | Meat and wool  | Crossing (7)         |
| Argentine Merino                             | Very fine wool | Selection (5)        |
| Uruguayan Merino                             | Very fine wool | Selection (5)        |
| <b>AUSTRALIA</b>                             |                |                      |
| Australian Merino                            | Very fine wool | Selection (5)        |
| Polwarth or Ideal                            | Fine wool      | Crossing (8)         |
| Corriedale                                   | Meat and wool  | Crossing (9)         |

- (1) Bred directly from Spanish merino stock, interpreting selection in the sense of racial purity without any infusion of blood other than that of the merino.
- (2) Merino x Border Leicester, a breed of double aptitude.
- (3) Rambouillet merino x Border Leicester (New Leicester or Dishley perfected varieties).
- (4) Some experts maintain the existence of crosses with non-merinos.
- (5) Pure selection of merino breeds from different countries (Spain, Germany, Austria, France).
- (6) Bred from Rambouillet from France and Germany.
- (7) Columbia = Rambouillet merino x Lincoln (meat-wool).
- (8) Australian merino x Lincoln (wool-producing breed with a better meat production than the pure merino).
- (9) Merino x Lincoln (double-purpose breed, meat-wool).
- (10) Merino A or Vermont; merino C or Delaine; merino B, between A and C.

*Breeds suitable for meat-production.*—Although all types of sheep produce meat in greater or lesser quantities, the efforts towards the breeding of real biotype digestive producers of high quality meat have, (in France, England, etc.) managed to obtain certain strains which have later become universally popular. These sheep maintain a good wool production, although of course their wool is coarser than that of the merino:



| GROUPS                          | BREEDS     | ORIGINS                                                                            |
|---------------------------------|------------|------------------------------------------------------------------------------------|
| English breeds with black faces | Southdown  | Sheep of Sussex and Kent improved by Ellmann and Webb                              |
|                                 | Shropshire | Ryeland x Southdown x Leicester                                                    |
|                                 | Hampshire  | Hampshire sheep x Southdown                                                        |
|                                 | Dorset     | Dorset sheep x Southdown                                                           |
|                                 | Oxford     | Hampshire sheep x Cotswolds                                                        |
|                                 | Suffolk    | Norfolk sheep x Southdown                                                          |
| French meat producing breeds    | Charmoise  | Sheep of the Massif Central improved by Malingié with the Kent breed, Romney Marsh |
|                                 | Berry      | Sheep of Berry-Champagne (Cher et Indre) improved by merino and Dishley            |
|                                 | Contentin  | Sheep from semi-central French Departments (Manche) improved by English breeds.    |
|                                 | Avranchin  | Idem. (Normandy) improved by cross-breeding with Dishley and New Kent              |

In other countries new strains have been evolved from these breeds for the increase in mutton production. The Southdown and Suffolk breeds have been widely crossed with very variable results.

*Breeds of double or mixed aptitudes.*—In general the definition «double-purpose» is reserved for the types of sheep in which meat and wool production is balanced, whereas that of «mixed purpose» is used to apply to the meat-wool producing types in which meat predominates. Of course there also exist types or breeds producing milk-wool. But the former type is more important. Some strains of sheep provide a triple production of meat, milk and wool, but with a lesser yield in each of these products. Below, we refer exclusively to the double or mixed purpose sheep producing meat and wool:

| <i>Economic Function</i>                         | <i>Country</i> | <i>Breed</i> | <i>Origin</i>                                                    |
|--------------------------------------------------|----------------|--------------|------------------------------------------------------------------|
| Breeds of double purpose (50-50 % meat and wool) | New Zealand    | Corriedale   | Merino x Lincoln                                                 |
|                                                  |                | Lincoln      | Id. of English Lincoln                                           |
|                                                  | England        | Romney Marsh | Improved Kent stock                                              |
|                                                  |                | Lincoln      | Improved Co. Lincoln                                             |
|                                                  | Germany        | Mele         | Merino x Border Leicester                                        |
|                                                  | U. S. A.       | Columbia     | Merino Rambouillet x Lincoln (with some Corriedale infiltration) |
|                                                  | Spain          | Molinillo    | Talavera sheep x merino x Southdown                              |

| Economic Function                                | Country | Breed                               | Origin                                                                                                                           |
|--------------------------------------------------|---------|-------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Mixed purpose breeds<br>(meat 60 % wool<br>40 %) | England | LONG WOOL                           |                                                                                                                                  |
|                                                  |         | Leicester or Dishley                | Leicester Sheep improved by Bakewell                                                                                             |
|                                                  |         | Border<br>Dishley                   | Idem.                                                                                                                            |
|                                                  |         | Cotswolds                           | Improved Cotswold sheep                                                                                                          |
|                                                  |         | South Devon                         | South Devon sheep x Leicester                                                                                                    |
|                                                  |         | Long-wool<br>Devon                  | Co. Devon sheep x Leicester                                                                                                      |
|                                                  |         | Roscommon                           | Only pure breed in Ireland                                                                                                       |
|                                                  |         | SHORT WOOL                          |                                                                                                                                  |
|                                                  |         | Ryeland                             | Hereford sheep x Merino                                                                                                          |
|                                                  |         | Dorset Horn                         | Dorset and Somerset (downs)<br>sheep x Leicester x Southdown                                                                     |
|                                                  |         | Black-face                          | Mountain breed from Scotland and<br>North of England                                                                             |
|                                                  |         | Cheviot                             | Sheep from Southern Highlands<br>of Scotland                                                                                     |
|                                                  |         | Herdwick                            | Mountain sheep from Lancashire<br>and other counties                                                                             |
|                                                  |         | Loak                                | Lancashire, Yorkshire and Derbyshire<br>sheep                                                                                    |
|                                                  |         | Dartmoor                            | Dartmoor x Leicester primitive<br>sheep                                                                                          |
|                                                  |         | Exmoor                              | Exmoor and Brendon x Leicester                                                                                                   |
|                                                  | Wales   | Welsh Mountain                      |                                                                                                                                  |
|                                                  |         | Glamorgan                           | Mountain breeds with various improvement<br>crosses                                                                              |
|                                                  |         | Radnor<br>Clun Forest<br>Kerry Hill |                                                                                                                                  |
|                                                  | France  | Ile-de-France or<br>Dishley-Merino  | Rambouillet merino x Leicester<br>(New Leicester or improved<br>Dishley varieties)                                               |
|                                                  |         | Precocious Merino                   | Selection among pedigree merinos<br>of Spanish origin some experts<br>maintain the existence of some<br>crosses with non-merinos |
|                                                  | Holland | Texel                               | Improved native sheep                                                                                                            |



*Milk Breeds.*—Bred from an ancestral stock of coarse wool sheep. Some are triple purpose (Spanish manchego; Italian Bergamasca and Biellesa, etc.). In the following table only the great milk breeds of very high yields are included:

| COUNTRIES           | BREEDS        | ORIGIN                                              |
|---------------------|---------------|-----------------------------------------------------|
| Germany and Holland | Wiltstermacht | German North Sea Coast sheep (Weser, Wilster, Elbe) |
|                     | Ostfrisen     | Eastern Dutch Friesian sheep                        |
| France              | Larzac        | Larzac sheep (Lozère, Hérault)                      |
|                     | Others        | Lacaune, Segala, Causse, Lauregais, etc.            |
| Spain               | Churra        | Long wool sheep from Tierra de Campos               |

*Other types of sheep.*—We shall not mention here the sheep population of those continents and countries, forming the general mass of wool producing stock, where improvement had been realized or where it is being attempted. Neither shall we refer to the special groups of sheep with long tails, short tails, wide tails, oily tails, oily group etc. and furrier sheep (Karakul among the oily tail group.) etc. Although they do indeed amount to many millions of heads, they are not of universal significance.

*Mutton Production.*—The following table constitutes an analysis by continents:

| Continents | Countries          | Annual Production<br>(metric tons) |         |
|------------|--------------------|------------------------------------|---------|
| AFRICA     | West Africa        | 8,000                              |         |
|            | Equatorial Africa  | 40,000                             |         |
|            | Algeria            | 25,000                             |         |
|            | Egypt              | 44,000                             |         |
|            | Ethiopia           | 120,000                            |         |
|            | Morocco            | 53,000                             |         |
|            | Tanganika          | 8,000                              |         |
|            | Tunisia            | 18,000                             |         |
|            | Uganda             | 11,000                             |         |
|            | Union of S. Africa | 76,000                             | 403,000 |
| AMERICA    | Argentina          | 51,000                             |         |
|            | Brazil             | 31,000                             |         |
|            | Canada             | 16,000                             |         |
|            | Chile              | 30,000                             |         |
|            | United States      | 237,000                            |         |
|            | Mexico             | 12,000                             |         |
|            | Peru               | 12,000                             |         |
|            | Uruguay            | 48,000                             | 437,000 |
| ASIA       | India              | 374,000                            |         |
|            | Indonesia          | 58,000                             |         |
|            | Iran               | 60,000                             |         |
|            | Iraq               | 24,000                             |         |
|            | Pakistan           | 61,000                             |         |
|            | Syria              | 18,000                             |         |
|            | Turkey             | 58,000                             | 653,000 |

| Continents                                                                                                              | Countries       | Annual Production<br>(metric tons.) |           |
|-------------------------------------------------------------------------------------------------------------------------|-----------------|-------------------------------------|-----------|
| EUROPE                                                                                                                  | Eastern Germany | 43,000                              |           |
|                                                                                                                         | Western Germany | 29,000                              |           |
|                                                                                                                         | Bulgaria        | 16,000                              |           |
|                                                                                                                         | Spain           | 88,000                              |           |
|                                                                                                                         | Finland         | 7,000                               |           |
|                                                                                                                         | France          | 100,000                             |           |
|                                                                                                                         | Greece          | 33,000                              |           |
|                                                                                                                         | Holland         | 5,000                               |           |
|                                                                                                                         | Ireland         | 14,000                              |           |
|                                                                                                                         | Iceland         | 6,000                               |           |
|                                                                                                                         | Italy           | 49,000                              |           |
|                                                                                                                         | Norway          | 15,000                              |           |
|                                                                                                                         | Portugal        | 11,000                              |           |
|                                                                                                                         | England         | 134,000                             | 550,000   |
| OCEANIA                                                                                                                 | Australia       | 268,000                             |           |
|                                                                                                                         | New Zealand     | 297,000                             | 565,000   |
| World total excepting the Soviet Union and<br>all countries with an annual production<br>of less than 5,000 metric tons |                 |                                     | 2,608,000 |

The following countries play a leading role as exporters on the world market: New Zealand, Australia, Argentina, Uruguay and the Union of South Africa. The United States, England and other European countries are the leading importers, or consumers of all the mutton they produce themselves (France, Spain, Italy, etc.).

The meat production of each country does not depend directly on the number of sheep reared there, but rather on the types and systems of production and development, which may be summarized as follows:

a) the production of meat is of *secondary* importance because the flocks are primarily wool producing, with a high proportion of merinos, raised in regions of low agricultural fertility.

b) the production of meat is of *intermediary* importance, in either double- or mixed-purpose sheep, with suitable breeds (Corriedale, Romney Marsh, Lincoln, etc.) in regions of normal or medium fertility.

c) the production of meat is *predominant*, in certain types of sheep, whose wool is of secondary value (Southdown, Suffolk, etc.) for high meat production good pasture of a high alimentary value is necessary as well as a favourable climate.

On the whole, system a) predominates, where the quality of the meat is of secondary importance and below market requirements; the modern double purpose breeds, together with improved methods of nutrition in fertile regions are gradually making it possible to attain a higher proportion of systems b) and c). A characteristic example is that of New Zealand. This country occupies first place in the world production of precocious lambs, which possess excellent qualities of tenderness and tastiness. This is due to various factors, such as a first-class system of raising sheep, the improvement of pastures by sowing and fertilizing and the diffusion of English black-face sheep, especially



of the Southdown strain, in cross-breeds with Romney Marsh and Corriedale. On the other hand, Australia, whose sheep population is far greater, produces much less mutton than New Zealand, although this does not mean that Australia is not one of the leading exporting countries. The United States has a wide demand for mutton on the domestic market, so that they produce mutton from meat producing sheep of merino origin (American Rambouillet) which are to a great extent cross-bred with black face sheep. England rears a wide variety of mutton breeds and is besides an importer of enormous quantities of meat.

*Wool Production.*—The figures covering the world production of wool tend to remain stationary, since the numerical increase of the sheep population is directed more towards the production of meat or to types of mixed or double purpose.

The world statistics dealing with the years from 1931 to 1952 show the following figures, (in thousands of metric tons, based on unwashed wool):

| Years     | Africa | America | Asia | Europe | URSS | Oceania | TOTAL |
|-----------|--------|---------|------|--------|------|---------|-------|
| 1931-1932 | 178    | 489     | 155  | 232    | 80   | 579     | 1,710 |
| 1941-1942 | 158    | 550     | 158  | 212    | 90   | 685     | 1,853 |
| 1951-1952 | 140    | 460     | 160  | 210    | 100  | 653     | 1 723 |

The table below indicates the wool production of the more important countries on the basis of unwashed wool or washed wool, as well as the yield in washing:

| Countries             | PRODUCTION —                        |             |           |
|-----------------------|-------------------------------------|-------------|-----------|
|                       | millions of metric tons on basis of |             | Yield in  |
|                       | Unwashed wool                       | Washed wool | washing—% |
| Australia             | 476                                 | 286         | 60        |
| Argentina             | 590                                 | 105         | 55        |
| New Zealand           | 177                                 | 106         | 60        |
| United States         | 177                                 | 59          | 50        |
| Union of South Africa | 105                                 | 53          | 50        |
| Soviet Union          | 100                                 | 35          | 35        |
| Uruguay               | 77                                  | 42          | 55        |
| Spain                 | 40                                  | 16          | 40        |
| England               | 39                                  | 20          | 50        |
| Turkey                | 33                                  | 13          | 40        |
| China                 | 30                                  | 9           | 30        |
| India                 | 25                                  | 8           | 30        |
| Brazil                | 21                                  | 11          | 50        |
| Italy                 | 17                                  | 7           | 40        |
| Iraq                  | 16                                  | 5           | 30        |
| Iran                  | 16                                  | 5           | 30        |
| Yugoslavia            | 16                                  | 6           | 40        |

| Countries       | PRODUCTION —                        |             |           |
|-----------------|-------------------------------------|-------------|-----------|
|                 | millions of metric tons on basis of |             | Yield in  |
|                 | Unwashed wool                       | Washed wool | washing—% |
| Rumania         | 16                                  | 6           | 40        |
| France          | 16                                  | 6           | 40        |
| Bulgaria        | 13                                  | 5           | 40        |
| Morrocco        | 12                                  | 5           | 40        |
| Germany         | 11                                  | 4           | 40        |
| Pakistan        | 11                                  | 3           | 30        |
| Other countries | 129                                 | 39          | 30        |
| TOTAL           | 1,723                               | 864         | 50        |

The figures covering the yield in washing have been calculated theoretically, and the world average is 50 % only thanks to the high yield and great quantities produced by Australia, Argentina, New Zealand, Uruguay, etc. These countries alone, together with the production of South Africa account for 1,035 thousand tons a year of unwashed wool (60 % of the world production) and 864 thousand tons of washed wool (70 % of the world production).

Australia produces 80 % of its wool with sheep of the merino type, and the rest with sheep of crossed breeds. New Zealand, on the other hand, produces 95 % of its wool with cross-bred sheep and the rest with merinos. Argentina produces a great variety of different types of fine wool. The Union of South Africa produces 65 % of its wool with merinos and 15 % with cross-bred sheep.

Highly populated countries, such as England, France, the United States, Japan and Germany import considerable quantities of wool. Some countries which produce a great deal of wool, such as South Africa also are big consumers and manufacturers. However they do export a great proportion of their produce and their annual consumption per inhabitant is small (0.437 kilos of washed wool). Argentina and Uruguay consume a great deal of wool (1.580 kilos and 1.922 kilos respectively per inhabitant per year), and they are also big producers. But the United States, which import a great deal of wool and do not export textiles, reach a consumption figure of 1.785 kilos per year while Canada remains at 0.855 kilos. After making great sacrifices in order to be able to import wool, Japan does not manage to consume more than 0.260 kilos. Western Germany and France, both of them importing countries, reach 1.164 and 2.570 kilos respectively. Spain, a relatively good producer, does not supply her market with more than 0.649 kilos of washed wool per inhabitant per year, while Italy, a big importer, reaches the figure of 1.170 kilos. England beats all records with 4.598 kilos, although much of this wool is first imported and manufactured into materials and then re-exported. Finally, Australia, although exporting a great deal, reaches the figure of 3.555 kilos and New Zealand that of 1.904 kilos per inhabitant per year.

Regarding the competition between wool and artificial fibres it is sufficient to state that in 1958 the world production amounted, as mentioned already,



to 1,723 thousand metric tons of unwashed wool. The amount of synthetic fibres was considerably greater than that of wool, reaching the figure of 2,470 thousand tons, while the amount of cotton was equivalent to 7,960 thousand tons.

*Production of Sheep's Milk.*—This is not easy to evaluate. The consumption of fresh sheep's milk is restricted to backward countries or those with a low production of cow's milk. By far the greater amount of sheep's milk produced is made into cheese. Countries such as France, Italy, Switzerland, Denmark, Holland, Germany, England, Spain, etc., all possess a wide choice of such cheeses, as well as cheese produced from cow's and goat's milk.

The table below constitutes a statistical survey, as accurate as circumstances permit, of the world's cheese production, using the milk of the three above-mentioned species:

| Countries             | Metric Tons of Cheese per year |
|-----------------------|--------------------------------|
| Austria               | 21.5                           |
| Denmark               | 81.6                           |
| Finland               | 22.9                           |
| x France              | 296.0                          |
| Western Germany       | 156.0                          |
| Ireland               | 2.0                            |
| x Italy               | 292.0                          |
| Norway                | 27.0                           |
| Holland               | 140.0                          |
| England               | 88.8                           |
| x Spain               | 16.2                           |
| Sweden                | 55.3                           |
| Switzerland           | 50.8                           |
| Union of South Africa | 12.2                           |
| Canada                | 38.3                           |
| United States         | 614.4                          |
| Argentina             | 109.2                          |
| Australia             | 49.2                           |
| New Zealand           | 105.0                          |

Those countries in whose cheese production a large proportion of sheep's milk is used have been marked with an X.

*Other Sheep Products.*—Besides the three principal products obtained from sheep, that is milk, meat and wool, there are others of lesser importance. One of these is closely linked with the way in which sheep are raised, and is of tremendous interest for the maintenance of the biological cycle of the soil, namely manure.

The remaining products (skins, hides, etc.) are derived from young and old animals in the slaughter or packing house. Furrier products of a high

quality do exist, such as those obtained from the Karakul breed and other similar strains, called Astrakhan, Persian Lamb, Breitschwanz, etc. Apart from these luxury skins there is nowadays a great demand for technically treated normal lamb skins, generally obtained from merinos or cross-bred sheep («agneau rasé», «mouton doré», etc.). These offer great possibilities for the sheep-skin industry, which was formerly despised. In some countries there has developed strong competition for shorn wool, obtained through maceration and depilation of the skins of animals which have been slaughtered with all their wool.

## II

### PROBLEMS OF NUTRITION IN THE IMPROVEMENT OF SHEEP

Except in those countries which dispose of extremely good and plentiful pastures in suitable climates, wool producing sheep are generally raised under very poor alimentary conditions, which strongly limit their possibilities of improvement. Investigations into the alimentary needs of livestock have generally been carried out with cattle, swine, horses and poultry. With the exception of some stall-fed or semi stall-fed types, sheep are generally left to graze and prefer to consume grass or cultivation residues. The variety of pasture is so great from one country to the next and even from one region to the next, that it is impossible to set up any universal norms in connection with this aspect of animal nutrition.

It is also a well-known fact, that different schools of experts on animal nutrition work in different feed units. Thus it should be borne in mind that the following surveys have been based on «Feed Units» (or «fodder», «Scandinavian», etc.) equivalent, in their energy-producing contents, to one kilo of barley grain, in accordance with the system used, for example, to calculate the feeding tables of Hansson and other similar tables. In accordance with this evaluation of the unit, the conservation ration of a normal type sheep may be considered to be as follows:

|                      |     |     |      |
|----------------------|-----|-----|------|
| Live weight in kilos | 30  | 50  | 70   |
| Feed Units per day   | 0.4 | 0.5 | 0.65 |

These figures apply to sheep resting in a sheepfold, which do not have to walk in search of pasture.

During the first youthful stages of their development, sheep need considerably more food in relation to their live weight, especially digestible proteins. Below, the outline of a table indicating *growing and conservation rations* from 5 to 120 kilos:



Growing and conservation rations for sheep expressed in feed units (FU)  
digestible protein (DP) and dry substances (DS)

| Live weight<br>kgs. | Per animal per day |      |      | Per FD |          | Per 100 kgs. live weight |      |      |
|---------------------|--------------------|------|------|--------|----------|--------------------------|------|------|
|                     | FU                 | DP   | DS   | DP     | DS       | FU                       | DP   | DS   |
|                     |                    | grs. | kgs. | grs.   | kgs.     |                          | grs. | kgs. |
| 5                   | 0.1                | 18   | 0.2  | 180    | 2        | 2.0                      | 360  | 4    |
| 10                  | 0.15               | 20   | 0.3  | 135    |          | 1.5                      | 200  | 3    |
| 15                  | 0.2                | 21   | 0.4  | 105    | (in      | 1.4                      | 140  | 2.7  |
| 20                  | 0.25               | 22   | 0.6  | 90     | near-    | 1.3                      | 120  | 2.5  |
| 30                  | 0.4                | 30   | 0.7  | 75     | ly all   | 1.3                      | 100  | 2.4  |
| 40                  | 0.45               | 35   | 0.9  | 75     | weights) | 1.1                      | 90   | 2.2  |
| 50                  | 0.5                | 40   | 1.0  | 75     |          | 1.0                      | 80   | 2.0  |
| 60                  | 0.6                | 45   | 1.2  | 75     |          | 1.0                      | 75   | 2.0  |
| 70                  | 0.65               | 50   | 1.4  | 75     |          | 0.9                      | 70   | 2.0  |
| 80                  | 0.7                | 55   | 1.5  | 75     |          | 0.9                      | 65   | 1.9  |
| 90                  | 0.75               | 60   | 1.6  | 80     | 2        | 0.8                      | 60   | 1.7  |
| 100                 | 0.8                | 65   | 1.7  | 80     |          | 0.8                      | 65   | 1.7  |
| 110                 | 0.85               | 70   | 1.8  | 80     |          | 0.7                      | 65   | 1.6  |
| 120                 | 0.9                | 80   | 1.9  | 90     | 2        | 0.7                      | 65   | 1.5  |

In connection with *production needs*, three points should be considered: a) wool — b) milk — c) supplementary ration (energy producing) to compensate for energy used up in grazing. This last point is especially important in the case of sheep raised on extensive pastures.

a) *Wool producing rations.* — In this regard food requirements are insignificant in quantity, but very important from the point of view of quality (protein necessary for wool formation). If a sheep produces three kilos of unwashed wool per year, that is, the equivalent of 8 grs. per day (this figure is approximate only since the growth of wool is not uniform throughout the year), 10 calories daily are required per gram of wool; that is  $10 \times 8 = 80$  calories a day, or the equivalent of approximately 0.05 feed units, indeed a small amount when seen quantitatively. But the requirements in protein are high: a sheep needs twice as much nitrogenous matter than keratin for its wool formation, amounting to a daily ration of 16 grams of protein, representing from one third to half of the protein requirements for conservation.

Thus they need feed units which are enormously rich in protein, for if 0.05 FD have to contain 16 grams of crude protein (CP), assuming and 80 % digestibility, this amounts to 12.8 grams of DP, or 256 grs. of DP  $\times$  FU, a very high figure indeed. The conservation ration only requires 75-90 grams of DP  $\times$  FU, rations for milk production should include 200 and the combined conservation-milk ration should include 110-160. For this reason it is obvious that the wool producing supplement supposes a considerable increase in protein. An animal with a high yield, producing some 10 kilos of unwashed wool per year, would need a daily supplement of 0.2 FU and 43 grs. DP. If this need is not taken into account, the wool production of many flocks in all countries is totally insufficient. (In Australia the average is 4 kilos per head per year, while in Spain it is less than 1.7 kilos.)

Necessary supplements for wool production:

| Annual<br>wool produc-<br>tion (kilos) | Daily needs |            |            | DP per FU<br>grs.                        | DS per FU<br>kgs. |
|----------------------------------------|-------------|------------|------------|------------------------------------------|-------------------|
|                                        | FU          | DP<br>grs. | DS<br>kgs. |                                          |                   |
| 1                                      | 0.027       | 4.3        | 0.030      | Approx.                                  | Approx.           |
| 1.5                                    | 0.030       | 7.5        | 0.050      | 260                                      | 2                 |
| 2                                      | 0.034       | 8.6        | 0.060      | (in all weights of<br>annual production) |                   |
| 2.5                                    | 0.040       | 10.7       | 0.080      |                                          |                   |
| 3                                      | 0.050       | 12.8       | 0.100      |                                          |                   |
| 3.5                                    | 0.057       | 15.1       | 0.110      |                                          |                   |
| 4                                      | 0.064       | 17.2       | 0.120      |                                          |                   |
| 4.5                                    | 0.072       | 19.3       | 0.140      |                                          |                   |
| 5                                      | 0.080       | 21.4       | 0.160      |                                          |                   |

As we have said already, it is essential to bear in mind the fact that the annual needs as indicated above are not constant throughout the year, since the growth of the wool varies from season to season. It should also be considered that from the point or view of quality, the nitrogenous content is of capital importance. In the ontogeny of the wool follicle and the building up of fibre, the influence of nutrition is obvious, there is no evidence to support the fact that the composition of wool contains a constant amount of aminoacid. However, its keratins seem to be fairly securely integrated by a known series of aminoacids, such as sulphurates and especially by cystine, whose presence is very constant, in spite of the fact that the dithiolic links are very feeble in the face of atmospheric and living agents, such as fungus and bacteria, which determine certain processes of oxidation which destroy them.



Apart from a high arginine content (amounting to nearly 20 % of the protein total of the wool's keratin) a large amount of cystine and other sulphurated aminoacids has been observed to be characteristic. The presence of these elements in wool seems to depend entirely on the animals' nutrition, since the thiosynthetizer capacity of the micro organisms of the belly is unable to alter the figure of sulphurate aminoacids of alimentary origin which are transformed by the animal. The protein synthesis of the belly therefore seems to serve other needs than those in connection with the production of keratin in wool.

The quality of the animal's nutrition during the first 18 months of its life imposes permanent limitations on its subsequent wool producing capacity. Underfed animals show fewer follicles, skin which is less well constructed and rougher and sparse wool of defective growth. Exactly the opposite occurs when the animals are from the beginning submitted to a good, well-balanced diet.

Other requirements of the animal's body absorb much of the protein which might be needed for wool production, (growth, milk production, gestation, reproduction, conservation requirements). Only 10 % of the aminoacids introduced are converted into keratins of wool, and in some special cases of hypo and even of hypernutrition, this figure is even reduced by 5-7 %. In general the introduction of sulphurate aminoacids into the rations acts as a limiting factor. For this reason, vegetable proteins are only to an extent of 30 % of biological value. In terms of protein feeding wool is, therefore, a rather expensive product.

Curiously enough, rations which are very rich in energy and especially in proteins increase the individual wool production, but diminish the fineness of the wool, and viceversa; it is notorious that the world's best types of fine wool producing sheep, classically inferior producers of meat and milk (except under the very best feeding conditions) come from countries with poor pasture. The length and resistance of the fibre, its uniformity, texture, softness, shine, etc., are all factors which are influenced by nutrition.

It is improbable that sheep are supplied to the limits of their genetic possibilities with aminoacids so as to produce the greatest amount of wool of which they are capable through heredity. On the contrary, from a protein point of view they always seem to be maintained in a state of hypernutrition in relation to their wool. On the other hand, the requirements of a maximum disproportionate production to the extent of its hereditary possibilities, would exceed the capacity of their digestive organs. Even in the case of animals consuming an excessive amount of protein but not having enough limiting aminoacids to cover their biological needs, it may occur that many aminoacids which are unnecessary for wool production are dissipated in excessive waste.

22.

b) *Milk producing ration.*—Sheep's milk, whose dry extract is richer than that of cows, requires more FU than the latter; one kilo of sheep's milk needs 0.60 FU with 200 grs. of DP per FU, or 120 grs. of DP per Kg. of milk.

Total conservation and milk producing needs of sheep of a live weight from 30 to 70 kilos, with milk productions varying from 250 to 1.500 grams daily, expressed in a percentage increase representing the total ration as compared with the mere conservation rations.

| Live weight | Milk prod per day | Per animal per day |      |      |            |      |      |       |      |      | Increase of the total ration over cost |      |     |     |     |
|-------------|-------------------|--------------------|------|------|------------|------|------|-------|------|------|----------------------------------------|------|-----|-----|-----|
|             |                   | Conservation       |      |      | Production |      |      | Total |      |      | per FU                                 |      |     |     |     |
|             |                   | FU                 | DP   | DS   | FU         | DP   | DS   | FU    | DP   | DS   | DP                                     | DS   | FU  | DP  | DS  |
|             | kgs.              | grs.               | grs. | kgs. | grs.       | kgs. | kgs. | grs.  | kgs. | kgs. | grs.                                   | kgs. | %   | %   | %   |
| 30          | 250               | 0.4                | 30   | 0.7  | 0.15       | 30   | 0.25 | 0.55  | 60   | 0.95 | 110                                    |      | 140 | 200 | 130 |
|             | 500               | 0.4                | 30   | 0.7  | 0.30       | 60   | 0.50 | 0.70  | 90   | 1.20 | 130                                    |      | 175 | 300 | 170 |
|             | 750               | 0.4                | 30   | 0.7  | 0.45       | 90   | 0.75 | 0.85  | 120  | 1.45 | 140                                    |      | 210 | 400 | 200 |
|             | 1000              | 0.4                | 30   | 0.7  | 0.60       | 120  | 1.00 | 1.00  | 150  | 1.70 | 150                                    |      | 250 | 500 | 240 |
|             | 1250              | 0.4                | 30   | 0.7  | 0.75       | 150  | 1.25 | 1.15  | 180  | 1.95 | 155                                    |      | 285 | 600 | 280 |
|             | 1500              | 0.4                | 30   | 0.7  | 0.90       | 180  | 1.50 | 1.30  | 210  | 2.20 | 160                                    |      | 325 | 700 | 300 |
| 40          | 250               | 0.45               | 35   | 0.9  | 0.15       | 30   | 0.25 | 0.60  | 65   | 1.15 | 110                                    |      | 140 | 190 | 125 |
|             | 500               | 0.45               | 35   | 0.9  | 0.30       | 60   | 0.50 | 0.75  | 95   | 1.40 | 130                                    |      | 175 | 280 | 150 |
|             | 750               | 0.45               | 35   | 0.9  | 0.45       | 90   | 0.65 | 0.90  | 125  | 1.65 | 140                                    |      | 200 | 370 | 180 |
|             | 1000              | 0.45               | 35   | 0.9  | 0.60       | 120  | 1.00 | 1.05  | 155  | 1.90 | 150                                    |      | 220 | 440 | 210 |
|             | 1250              | 0.45               | 35   | 0.9  | 0.75       | 150  | 1.25 | 1.20  | 185  | 2.15 | 155                                    |      | 270 | 530 | 240 |
|             | 1500              | 0.45               | 35   | 0.9  | 0.90       | 180  | 1.50 | 1.35  | 215  | 2.40 | 160                                    |      | 300 | 610 | 270 |
| 50          | 250               | 0.5                | 40   | 1.0  | 0.15       | 30   | 0.25 | 0.65  | 70   | 1.25 | 110                                    |      | 130 | 175 | 125 |
|             | 500               | 0.5                | 40   | 1.0  | 0.30       | 60   | 0.50 | 0.80  | 100  | 1.50 | 130                                    |      | 160 | 350 | 150 |
|             | 750               | 0.5                | 40   | 1.0  | 0.45       | 90   | 0.75 | 0.95  | 130  | 1.75 | 140                                    |      | 190 | 325 | 175 |
|             | 1000              | 0.5                | 40   | 1.0  | 0.60       | 120  | 1.00 | 1.10  | 160  | 2.00 | 150                                    |      | 220 | 400 | 200 |
|             | 1250              | 0.5                | 40   | 1.0  | 0.75       | 150  | 1.25 | 1.25  | 190  | 2.25 | 155                                    |      | 250 | 475 | 225 |
|             | 1500              | 0.5                | 40   | 1.0  | 0.90       | 180  | 1.50 | 1.40  | 220  | 2.50 | 160                                    |      | 280 | 550 | 250 |
| 60          | 250               | 0.55               | 45   | 1.2  | 1.15       | 30   | 0.25 | 0.70  | 75   | 1.45 | 110                                    |      | 125 | 165 | 120 |
|             | 500               | 0.55               | 45   | 1.2  | 0.30       | 60   | 0.50 | 0.85  | 105  | 1.70 | 130                                    |      | 150 | 230 | 140 |
|             | 750               | 0.55               | 45   | 1.2  | 0.45       | 90   | 0.75 | 1.00  | 135  | 1.95 | 140                                    |      | 180 | 300 | 160 |
|             | 1000              | 0.55               | 45   | 1.2  | 0.60       | 120  | 1.00 | 1.15  | 165  | 2.20 | 150                                    |      | 200 | 370 | 180 |
|             | 1250              | 0.55               | 45   | 1.2  | 0.75       | 150  | 1.25 | 1.30  | 195  | 2.45 | 155                                    |      | 230 | 430 | 200 |
|             | 1500              | 0.55               | 45   | 1.2  | 0.90       | 180  | 1.50 | 1.45  | 225  | 2.70 | 160                                    |      | 260 | 500 | 225 |
| 70          | 250               | 0.6                | 50   | 1.4  | 0.15       | 30   | 0.25 | 0.75  | 80   | 1.65 | 110                                    |      | 120 | 160 | 115 |
|             | 500               | 0.6                | 50   | 1.4  | 0.30       | 60   | 0.50 | 0.90  | 110  | 1.90 | 130                                    |      | 145 | 225 | 135 |
|             | 750               | 0.6                | 50   | 1.4  | 0.45       | 90   | 0.75 | 1.05  | 140  | 2.15 | 140                                    |      | 170 | 280 | 150 |
|             | 1000              | 0.6                | 50   | 1.4  | 0.60       | 120  | 1.00 | 1.20  | 170  | 2.40 | 150                                    |      | 190 | 340 | 170 |
|             | 1250              | 0.6                | 50   | 1.4  | 0.75       | 150  | 1.25 | 1.35  | 200  | 2.65 | 155                                    |      | 220 | 400 | 190 |
|             | 1500              | 0.6                | 50   | 1.4  | 0.90       | 180  | 1.50 | 1.50  | 230  | 2.90 | 160                                    |      | 250 | 460 | 210 |

c) *Supplementary rations to make up for Pasture expenditure.*—The Conservation ration is insufficient for the replacement of energy expended in the considerable displacements enforced on sheep by the need of the search for pasture and water. Such displacements suppose a considerable waste of energy and also, although to a lesser degree, a waste of protein, due to muscular wear and tear and the increased effort imposed on the organic system. The supplement required by sheep to enable them to traverse their pasture-land daily is increased according to the size of the latter. It is normal for the



sheep to cover from five to ten kilometers a day, especially in regions with poor pasture.

The energy-expenditure incurred in the process of grazing varies also with the gradient of the land. In flat pastures the expenditure is less. In general, it may be calculated at fifty calories for every hundred kilos of live weight per kilometer, with a further ten calories per hundred kilos for every hundred meters in change of altitude:

| Live weight<br>(kgs.) | Kilometers traversed on flat ground |        |        |        |         |
|-----------------------|-------------------------------------|--------|--------|--------|---------|
|                       | 2 kms.                              | 4 kms. | 6 kms. | 8 kms. | 10 kms. |
|                       | (calories)                          |        |        |        |         |
| 20                    | 20                                  | 40     | 60     | 80     | 100     |
| 30                    | 30                                  | 60     | 90     | 120    | 160     |
| 40                    | 40                                  | 80     | 120    | 160    | 200     |
| 50                    | 50                                  | 100    | 150    | 200    | 250     |
| 60                    | 60                                  | 120    | 180    | 240    | 300     |
| 70                    | 70                                  | 140    | 210    | 280    | 350     |
| 80                    | 80                                  | 160    | 240    | 320    | 400     |
| 90                    | 90                                  | 180    | 270    | 360    | 450     |
| 100                   | 100                                 | 200    | 300    | 400    | 500     |
| 110                   | 110                                 | 220    | 330    | 440    | 550     |

If these calory figures are changed into FU with 70-90 grs. of DP and about 2 kgs. of DS per FU we should obtain:

A daily supplement in % of the conservation ration for sheep at daily pasturage according to the amount of kilometers covered and to their live-weight.

| Live weight<br>(kgs.) | Kilometers covered on flat ground |        |        |        |         |
|-----------------------|-----------------------------------|--------|--------|--------|---------|
|                       | 2 kms.                            | 4 kms. | 6 kms. | 8 kms. | 10 kms. |
|                       | FU of conservation ration         |        |        |        |         |
| 20                    | 1                                 | 4      | 7      | 10     | 13      |
| 30                    | 2                                 | 5      | 8      | 11     | 14      |
| 40                    | 3                                 | 6      | 9      | 12     | 15      |
| 50                    | 4                                 | 7      | 10     | 13     | 16      |
| 60                    | 5                                 | 8      | 11     | 14     | 17      |
| 70                    | 6                                 | 9      | 12     | 15     | 18      |
| 80                    | 7                                 | 10     | 13     | 16     | 19      |
| 90                    | 8                                 | 11     | 14     | 17     | 20      |
| 100                   | 9                                 | 12     | 15     | 18     | 21      |
| 110                   | 10                                | 13     | 16     | 19     | 22      |

A sixty kilo sheep which covers six kilometer a day requires a supplementary ration of eleven per cent, on the FU of the conservation ration, which amounts to 0.6 FU per sheep per day. 11 % of 0.6 FU come to approximately 0.07, that is, to practically 0.1 which, added to 0.6 FU gives 0.7 FU per sheep per day for conservation ration plus pasture supplement, without counting any other production supplement. The 0.7 FU with 75 grs. of DP per FU and 2.0 kilos of DS per FU, constitute 52.5 grs. of DP and 1.4 kilos of DS per animal per day for the total conservation ration including pasturage, assuming that the sheep is left to graze on flat ground, for if this is not the case it is necessary to add the supplement for gradient as indicated in the above table.

*Lamb feeding* has to be divided into three categories, according to the purpose for which the lamb is being raised:

a) *Lambs slaughtered before being weaned.*—In general these are pure-bred lambs of strains which are milked. They are slaughtered at an age of between four and six weeks, weighing from five to twelve kilos live weight and have never been fed on anything but mother's milk. Their daily growth may give some idea of the mother sheep's production, whenever the exact relation existing between the milk consumed and the daily increase in weight is known.

| Lamb's daily increase<br>in weight<br>Kgs. | Quantity of milk consumed<br>from the mother<br>Kgs. | Quantity of milk needed<br>per kilo of increase in<br>weight per day<br>Kgs. |
|--------------------------------------------|------------------------------------------------------|------------------------------------------------------------------------------|
| 0.10                                       | 0.800                                                | 8.000                                                                        |
| 0.150                                      | 0.950                                                | 6.300                                                                        |
| 0.200                                      | 1.140                                                | 5.700                                                                        |
| 0.250                                      | 1.340                                                | 5.300                                                                        |
| 0.300                                      | 1.600                                                | 5.300                                                                        |

As soon as they are one month old, lambs begin to graze, and they may begin to consume concentrated foodstuffs whenever it is desired to speed up their growth. On such foodstuffs they can grow at the rate of from 150 to 200 grs. daily with from 20 to 22 kilos live weight being the slaughter deadline, which may be obtained with the same supplement as that given to the lamb in winter: cereal and leguminous straws, some mangled cereals (oats, barley, corn) or leguminous straws and hay, dehydrated alfalfa or wheat in variable quantities, from 25 to 50 grs. a day at first (5 to 8 weeks) and 100 to 200 grs. a day during the last two or three months.

b) *Lambs slaughtered after weaning.*—Lambs which are to be fattened up to a weight of 30 or even 40 kilos should be separated from their mothers when they are about three months old. At this age growth continues at the rate of from 150 to 200 grs. a day according to the breed and their nutrition.



Supplements of hay, dehydrated alfalfa, leguminous straws, mangled grain of cereals or leguminous grains, wheat or oily seed cakes, should amount to approximately 200-500 grs. daily, apart from pasturage.

c) *Lambs for reproduction* (males and females).—These should not be weaned until they have reached the age of 7-8 weeks. Their daily growth should amount to 120 grs. as a minimum in small breeds (merinos) and to 150 grs. in medium sized and large breeds. Their nutrition should include supplements which will permit them to reach their maximum weight such as mineral and vitamin additions which will develop their bone-structure. However, exaggeratedly voluminous and concentrated feeding should be avoided, in order not to overdevelop their digestive apparatus.

In relation to the needs of lambs, refer to a previous table indicating the conservation requirements of wool producing sheep. The same figures are valid for lambs, since it is necessary to increase their grazing supplements in accordance with the number of kilometers covered daily.

*Special circumstances in connection with the mineral and vitamin contents in the feeding of sheep.*—In relation with other nutritive influences on the growth of wool, such as vitamin A, copper, cobalt, zinc, molibdene, etc., etc., they are generally of a local or regional character, and for this reason they are not dealt with very extensively in this study, since their great variety does not permit it. Nevertheless, due to their importance and in connection with the need for minerals, we consider that their lack or insufficiently balanced contributions in massive elements and oligoelements are of even greater importance than a possible lack of nitrogenades, which natural feeding will manage to provide in fairly correct doses in pasturage, together with the necessary vitamins. On the other hand, any lack or irregularity in the mineral content of the animal's feed is due to the composition of the grass, so that the geological and chemical constitution of the latter plays an important part in the raising of sheep. Areas which are traditionally known to be lacking in specific mineral substances, cause sickness or produce deficiencies in the production of livestock. Concretely these deficiencies and irregularities manifest themselves in different aspects of the sheep's development, its corporal growth, its milk production and, to a great extent, in its wool.

It is very common for mountain pastures to be lacking in sodium. Therefore shepherds usually give common salt to their flocks. Modern methods have substituted common salt by powdered mineral mixtures, or by licking stones of a more complex composition, containing salts of calcium, iron, copper, magnesium and other mineral substances, which are, in very small doses, of benefit to the vital mechanism of the animals. The generalized use of these mixtures represents a great remedy for mineral deficiencies in wool producing stock.

A balance in phosphorous and calcium requirements in milk sheep and their lambs may be achieved by distributing in the sheepfold, 15 to 20 grs. per sheep per day of a mixture containing phosphate calcium, in the form of bone flour or biphosphate of calcium. This mixture should consist of the following ingredients: 400 grs. of phosphate calcium, 300 grs. of sodium chloride denaturalized by a ferric salt, 200 grs. of fine calcium carbonate, 100 grs. of magnesium sulphate.

A deficiency or irregularity in certain oligoelements containing oxide-reduction systems which intervene in the formation processes of proteins and wool fibres (such as zinc, cobalt, iron, copper, molybdenum, etc.) may cause serious harm to the quality of wool, the regularity of its texture, its length, the formation of its scales, resistance, shade, colour and shine; the secret of the high production in countries possessing sufficient pasture which nevertheless is of poor quality, lies in the fact that these oligoelements are well-balanced. The low quality and deficiencies in the production of wool per head in many of our regions, are due to a lack of these primary minerals, which have not yet been studied sufficiently and which are so closely connected to the composition of the soil.

Regarding vitamins, sheep seem to suffer, without a doubt, from a lack of Vitamin A only. This applies especially to lambs and rams used for breeding-purposes. Green grass contains great quantities of carotin and provitamin A, which may stay in the sheep's organism, especially in the liver.

During long periods of drought, when pasture-lands are dry or very scarce, dried vegetable organisms contain but traces of Beta-Carotin, which may easily be destroyed by an excess of oxygen or sunlight. If the preceding period has besides been one of scarce alimentation, the animal will have been unable to set up sufficient reserves of carotin. Besides, all dry supplements consisting of hay or cereal or leguminous grain, etc. (with the exception of yellow corn), contain only very small quantities of carotin which cannot make up for the deficiency; only very high quality hay preserves small amounts of provitamin A some months after it has been dehydrated, although it loses nearly 80 % when dried by the sun, so that this procedure of drying renders it almost totally deficient in the above-mentioned provitamin.

Vitamin A is very important in the nutrition of sheep, it is the most effective growth-factor, of primary importance in the development of young animals, which at birth possess only very slight reserves, depending almost entirely on the content of colostrum and later, on the mother's milk. When the ewe's rations are correctly balanced from the point of view of providing provitamin A, all goes well, but when they are insufficient, the lambs suffer disorders in their growth and wool production, which are also reflected in the state of the meat, as well as in the wool production of the ewes.

A deficiency in vitamin A produces sterility in meat producing sheep and various metabolic disorders in ewes. The administration of Vitamin A supplements to ewes during periods of deficient or non-existent green feed is absolutely necessary and is carried out as a matter of course in the raising of sheep in numerous countries.

Regarding other vitamin deficiencies in wool producing stock, it has already been pointed out that they are not very common. A lack of Vitamin A is one of the most frequent causes for economic losses. Naturally, it should be taken into account that preventive treatment involves a certain expenditure, but this will pay for itself in the long run through a gain in weight, improvement in the quality of the lamb, an increase of fertility in rams and of fecundity in ewes, lactation capacity and a decrease in losses.

Finally, some words should be added regarding the administration of urea to ewes to make up for protein deficiencies which may occur when rations are too rough, in periods of drought, or when pasture and protein supplements are too expensive. The addition of urea to the rations has proved



to give excellent results from the point of view of nitrogenous additions, since that substance consists of 46 % nitrogen, a considerable part of which may be converted into proteins by the bacteria of the sheep's belly. The animal can therefore make use of the bacterial proteins as food. Urea, however is toxic under certain conditions especially when the appropriate dose is exceeded. Besides, if the belly bacteria do not possess a rich supplement of carbohydrates, this substance will not function well. Urea ought to be used under the most satisfactory conditons, together with hydrocarbonate supplements, such as cereal grains. At the same time it would be advisable to add small amounts of sodium sulphate. A dose exceeding 6 grs. per adult head per day is never recommended nowadays. When the rations are rich, or the pasturage abundant, it may be administered on alternate days or twice weekly. It is also useful to employ powdered molasses mixed with urea. In any case, the last word has not yet been spoken in this connection and experiments are being continued in various research centers; the economic factor should not be disregarded, although in certain countries it may be in favour of the use of urea, due to the fact that this substance is inexpensive there. In other countries, however, prices of this substance are prohibitive.

## CONCLUSIONS

### *To Part I*

1. The species of Sheep, one of the most ancient to be raised by Man, has throughout its history remained almost immutable in its morphological and genetic components and in its methods of utilization, but in modern times it is being incorporated into the great, world-wide currents of zootechnics, dividing into biotypes of very great economic interest and evident specialization.

2. Wool production has been and always will be of prime importance in the raising of sheep, especially since it cannot be produced by any other animal species. Nevertheless, in future it should be attempted to obtain types of sheep which are capable of producing certain qualities and individual yield in accordance wiht the demands of a sound livestock economy.

This applies especially to the merino and fine cross-bred strains, which may be divided into two groups:

a) those capable of producing very fine, uniform wool, whose length and resistance, whiteness, elasticity and homogeneity (absence of dead hairs, seeds, impurities, etc.) should reach the highest possible degree. Of this the Australian merinos are an outstanding example, and they may also be raised to a certain point in the other countries, where they are common, such as Argentina, Uruguay and South Africa. Although with some difficulty, they can also be produced in countries of a great demographic density (especially in Europe).

b) Merinos and cross-breds producing less fine wool, whose meat production may be increased and precocity developed on improved pastures. These strains are represented by precocious merinos and their derivations, cross-bred animals (Corriedale, Polwarth, Columbia, etc.) which, together with the meat-

producing strains, can supply the market with enormous quantities of extraordinarily fine mutton.

3. The production of meat, based on cross-bred strains and especially on classical pure meat producing types, will in future be called upon to assume outstanding importance in the production of sheep. Countries with poor pasture land and difficult climates, such as those on the Mediterranean, which are nevertheless able to improve their agriculture and pasturage, will have to pay more attention to the development of such cross-bred types, whose wool is of good quality, but which also provides considerably amounts of first-class meat. This will obviously mean a decrease in the raising of fine-wool strains and an increase in the raising of medium-fine wool types with an aptitude for meat production.

4. The production of ewe's milk must be subjected to intense selection in cases of biotypes suitably for this specialization and in regions where sufficient pasture-land and a suitable climate assures a high milk production. Coarse wool animals with a low or even average milk production will always be uneconomic, because their low meat-wool yields are not compensated by a high milk production.

5. Because of its relatively short life cycle and in view of the primitive methods which have until now been used in their development, it is obvious that sheep can produce breeds and types of a highly specialized nature on the basis of suitable crosses. The point of departure for the most efficient form of zootechnics in this species which permits considerable consanguinity has always been provided by the local type of native ewe (improved by suitable crosses with hyper-specialized biotypes). Today these types are available in all the specialized lines of production, and also in those of double or mixed purpose production, so that this should be the genetic method by which it should be possible, with a subsequent stabilization and continued selection, to constitute in each region the type of sheep which corresponds to its characteristics of soil and climate.

6. Multiple production in one and the same type of animal should, if possible, be avoided. With this idea in mind the following list has been drawn up, showing the specialization permissible in accordance with the different biotipological groups of our modern sheep:

- a) wool (merinos)
- b) wool-meat (merino crosses with precocious or meat-producing strains)
- c) meat (English and French breeds of high meat production)
- d) meat-wool (refinement of the wool of these meat breeds by means of crosses with merinos)
- e) milk (French, German strains, etc. of high milk production)
- f) milk-meat-wool, in improved triple production, as a last resort the case of unspecialized breeds raised on poor pastures in unfavourable climates.

7. The standardization and normalization of all wool producing stock and their products, together with a world-wide introduction of uniform wool classifications, international meat and cheese categories, are, although difficult to achieve, nevertheless aims of the greatest importance to sheep farmers, business men and industrialists, who work with sheep and their products, just as it is important to make the consuming public aware of the valuable raw materials which sheep can provide for the benefit of humanity.



*To Part II*

1. It is necessary to establish an exact relationship between the quality and quantity of pasturage on one hand, and the numerical mass of sheep to be sustained, on the other hand, in accordance with their requirements for conservation and production.

2. Due to the fact that this is rarely taken into account, the individual yields of sheep are low, especially in countries with poor pastures and a difficult climate, and where the pastureland is being grazed excessively. An adjustment between the possibilities of the pasture and the number of sheep raised on it would increase the individual yield.

3. Through pasture, the composition of the soil, has very powerful influence on the aforementioned yields and it is also reflected in the morphology and in the vitality of the animals, that is to say, in the general economy of sheep-raising.

4. Usually nutrition by pasture alone is not sufficient for feeding the sheep throughout the year, since strong changes of climate impose seasonal and annual modifications on the sheep and their products.

5. When the system of outdoor grazing is used, a careful calculation of the alimentary requirements of the sheep as compared with the possibilities offered by the pasturelands, imposes the need, in a great number of cases, for the introduction of supplementary rations, with rough feeds (cereal or leguminous straws, runner vines, olive refuse, etc.) or concentrated feeds (hay, cereal or leguminous grain, oily seed cakes, dehydrated greens, etc.) during critical periods of the year, in order to prevent great losses in meat, milk and wool production, by means of regulating the nutrition of the flock, thus avoiding the period of recovery which follows periods of hunger.

6. Except during the periods mentioned already, deficiencies are not predominantly concerned with protein, especially in conservation and pasturage rations, whose nitrogenous needs are modest, but rather with mineral substances and vitamin A. Nutrition by grazing should be supplemented by rough feeds, since this is not only advisable, but even favourable to production, from both the physiological and economic points of view.

7. Mineral supplements are absolutely necessary, especially in regions where their lack or insufficiency has been observed, and their constant use is recommended with a view to the production of wool, meat and milk in sheep.

8. Sheep do obviously provide the mixed feed industry with a wide field for action, in the way of studying the convenient mixtures to satisfy the biological necessities of the stock in periods of hunger and meet the economic requirements of the breeder.

9. Well balanced nutrition, the readjustment of the number of heads in accordance with the possibilities of the pasturelands, well directed genetic selection, the fight against sickness in sheep, the possible implantation of flocks in newly irrigated regions, the construction of winter sheepfolds, the improvement of the individual yields subsequent to improved nutrition, are all normal channels for the evolution of the present-day type of sheep towards the new forms and yields made possible by progressive methods in the raising of livestock.

## DISCUSSION

MODERATOR. Now, to the questions.

*Dr. Peruchon de Brochard* (France). In France two different methods apparently contradictory are proposed to produce pigs with the minimum amount of fat possible. The first one consist of feeding the animal, from a liveweight of 20 kilograms until reaching 100 kilograms, on an unrestricting basis, a ration rich both in energy and proteins, for the purpose of reaching the 100 kilograms level at an earlier age. The second method is to restrict the feed since the 70 kilograms until 100 kilograms approximately. I would like to know the speakers' opinion regarding these methods.

*Dr. Lush* (U. S.). We do not, in the United States, make any restriction in the feed.

*Dr. Venge* (Sweden). Maybe *Dr. Clausen* should be asked this question. In Sweden we used restricted feeding during the whole fattening period.

MODERATOR. That seems a little paradoxical, doesn't it? This question really applies to nutrition rather than genetics, for the purpose of producing a leaner carcass. In Scotland we have adopted restricted feeding for the whole fattening period.

*Dr. Berge* (Norway). I will try to answer this question. Some interesting research has been performed in England using pigs fed 20 per cent less food than they would normally take when fed ad libitum. At 10 generations they found carcasses that were leaner as compared to the ones from pigs fed ad libitum, which produced fatter carcasses. Now, we would like to know whether it will be possible to obtain lean carcasses by selecting animals placed under restricted feeding, in order to have a rapid fattening of the animal.

*Dr. Mason* (Scotland). Your answer interests me very much.

*Dr. Varela* (Spain). In which proportion does the speaker consider that food utilization is a genetic function and not an adaptation one? Attempts have been made to increase the capacity of fibre utilization on the part of the Spanish autochthonous pig by crossing breeding with Large-White, without being able to obtain over 20 % of total performance, while it is physiologically possible with the autochthonous pig to arrive at a 60 %.

MODERATOR. It appears that local sows can digest a higher amount of fibre because they are used to it, but only a 20 % in the case of cross-bred animals, isn't it?

*Dr. Varela* (Spain). Yes sir, exactly.

*Dr. Lush* (U. S.). I cannot answer this question, as there are not available data regarding heritability of digestibility capacity.

*Dr. Martín Vaquero* (Spain). If we have a herd with a bull to increase milk yield in the low production cows and another bull to improve anatomical conformation of the highly productive cows which then will be the most effective daughter-dam progeny test or the contemporary comparison? The daughter-dam test presents a disadvantage in that from the time the mother is controlled until one starts daughter's control, there is a four years lapse of time. As for the contemporary comparison method there is the tendential election of daughters. I woul appreciate an answer regarding these problems.

*Dr. Lush* (U. S.). I think *Dr. Vaquero's* question has a pretty clear



answer. Contemporary comparisons are better than daughter-dam tests, because the latter requires too much time. The contemporary comparison methods offer more advantages, except when the daughters and the bull belonging to the same herd are not contemporary, in which case we must establish an age correlation, using as daughters' age the average age of the group or herd. You are talking about dairy cows, in which case the age difference may give a little advantage to daughter-dam test over contemporary comparison. Have I understood your question properly?

*Dr. Vaquero* (Spain). Yes, Sir, perfectly well. Now, as regards contemporary comparisons, I have noticed the difficulty presented by the tendential election of the daughters by the bull. Could you please explain this in more detail?

*Dr. Lush* (U. S.). What one can do in selecting the high cows to breed to one bull and the low ones to breed to another is so limited that this would be a minor source of error. If you mean in comparing the daughters with the average of all cows of the herd, you have a point there, that the average of these cows includes several who have survived several colleagues, so that the daughters are less selected than the average of the cows in the herd. They are also less selected than their dams because the cows which have the most daughters are the cows who have lived the longest in the herd. So you do not get rid of selection problems in comparing daughters with dams. Dr. Robinson believes you should compare the daughters only with their contemporaries of the same age. I do not share his doubts in that. He thinks age correction factors are not trustworthy enough. I believe they are trustworthy enough when averaged over many herds. There are differences of opinion on that, but I think there can be no difference of opinion about the fact that the year to year changes in production from unrecorded and uncontrolled circumstances are a major source of error. When one uses daughter-dam he automatically puts that difference into his problem. If he uses contemporary he puts that out. He may put in a little more trouble for selection, but that is likely to be minor.

*Dr. Venge* (Sweden). I agree completely with Dr. Lush but I should like to mention that in Sweden we have difficulties in performing progeny tests on contemporary comparisons. We therefore use the yield of all daughters from 4 to 6 days up to fecundation. Then we correct the yield. That is in order to avoid selection among the daughters before 1 1/2 months.

*Dr. Berge* (Norway). Well, this problem is very important in all selection. If we should select, if we should compare mother/daughter, or only the daughter in average. Well, during the last war in Norway, we had great differences in production from year to year and only comparisons between daughters and dams were absolutely no use. I think they had the same problem in Denmark too. They could not use comparisons of mothers and daughters. Then it was better to use the daughters alone to compare with the herd, but we had problems there too. When the herds are small, as they usually are in Norway then it is difficult to compare the daughters with the average of the herd too. The daughters will make a very great percentage of the herd in Norway. So we had to think of both those problems.

*Dr. Mason* (Scotland). Thank you. Well, we all agree that daughter/dam comparisons are inferior to contemporary comparisons.

Now, let us make a little Resumé of this Panel:

*Animal Breeding and Genetics: Resumé*

1. *Past and future.* The graphs which Dr. Lush showed demonstrate that, with the help of improvements in feeding, the livestock breeder has achieved great improvements in the productivity of his animals. The appearance of the geneticist is indicated by the increased slope of the U. S. egg production curve in the 1930's. Otherwise his influence has not been pronounced. He can add refinements to the well-tried methods of the breeder but, so far, he has not produced any new tricks. He can help to define more accurately the aims of selection in order to avoid effort being wasted on uneconomic or nonheritable characters. He can apply exact methods of measurement to replace eye appraisal so as to reduce the rate of diminishing of the return. He can examine each situation and calculate whether improvement will be most rapid by mass selection, progeny- or sib-testing, and he can work out the optimum structure of the breeding population. He can suggest under what circumstances crossbreeding may be advantageous and whether inbreeding has any constructive rôle to play. The papers of Dr. Berge and Dr. Venge gave detailed examples. The recipe is still the same: Go bald-headed in selecting for the character you want. Avoid inbreeding like the plague. Exploit hybrid vigour whenever possible.

2. *Choice of character(s).* The choice of character is easy for milk cattle but it may be complicated by necessary attention to solids-not-fat. For beef cattle and pigs we want economic production of lean meat. In both these animals the interest is now in finding a method for measuring the carcass characters in the live animals (Berge). For dual-purpose cattle and sheep we have the problem of two or more products which may be partially incompatible (Cuenca).

3. *Size of unit.* With all species the breeding unit is becoming larger following the realization that effective selection is only possible in large units. With dairy cattle and, very recently, with pigs (in Norway) the unit is the artificial insemination centre. For beef cattle and pigs it is the performance or progeny testing station. Many sheep flocks are large enough to be suitable selection units in themselves (especially in Australia and the Far Western United States). Very often the effect of this change is to take the breeding out of the hands of the pedigree breeder and put it into the hands of the A. I. organisations or large commercial breeders. This effect has been most striking in the poultry industry where a few large firms now produce all the breeding stock in U. S. A. This transformation of the industry is spreading fast in Europe.

4. *Research and improvement.* These large units not only accelerate improvement but furnish the basic research data on which further breeding plans can be based. For instance, Dr. Venge presented us with many figures on pig genetics, most of which came from progeny testing stations.

5. *Environment and selection.* In general it is wise to select animals in the same environment in which they are to be exploited. This should achieve the local adaptation of the type Dr. Cuenca referred to for sheep. Under certain circumstances (e.g. for reduced carcass fat), it may be advisable to select on a restricted diet in order to produce a strain which will not get too fat on an *ad lib.* diet.



Sometimes it may be possible to select on a correlated character, e. g. sleek-coated cattle for the tropics, LK sheep (low potassium in the blood cells) for a hot/dry environment (Merino, Sardinia).

But we must not expect miracles from the geneticist. Sudden leaps in production are possible from nutritional advances like antibiotics and oestrogens. The effect of the geneticist will be small but cumulative and permanent.

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### PANEL III

*Moderator (Dr. Kohn-Scotland)*

#### RECENT ADVANCES IN THE FIELD OF VITAMIN A

BY

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There is no need to stress the importance of Vitamin A, as even ruminants that are practically independent of supply of Vitamin B Complex, have a dietary need of Vitamin A. All domestic animals, as well as man, have therefore a need for a fairly constant supply of this vitamin, as the vitamin A stores which accumulate in the liver under practical conditions will last only for limited periods of deficient supply. Even today there are reports of widespread conditions of Vitamin A deficiency in cattle during the winter in northern Yugoslavia (1) and we all heard of the case reported by Dr. Beeson, which of course is of quite a different type.

May I add that a few years ago we had in Israel a fairly difficult vitamin A situation with respect to both, humans and cattle, because of the sudden increase of both these populations. The situation has now normalized through a more plentiful supply of vegetables and milk for human consumption and through the expansion of forage production. And let us not forget that under the usual intensive conditions of cattle breeding in Israel there is a fairly continuous supply of green fodder throughout the whole year. Actually in contrast to the situation in more northern countries, not only the green fodder supply is more plentiful in winter than in summer, but the carotene content is also higher during the winter months (2).

Quite apart from the «usual» interest in all aspects of vitamin A metabolism, in recent years there has been a fruitful research in the occurrence and activity of forms other than the all-trans-alcohol, not small part of this research being due to the group of workers headed by our Chairman. Their



finding (3) of vitamin A activity in fish eggs being due mainly to the aldehyde form suggest the necessity of checking if in other cases the presence of the aldehyde has not been overlooked and the vitamin A activity has not been underestimated. This might happen since the aldehyde is destroyed by the usual saponification step. The same workers also estimated (4) the biological activity of the 11-cis form (about 25-35 % of the all-trans form) and demonstrated its conversion to the usual form in the rat, while Bruggerman and Tiews (5) showed the same thing regarding the 13-cis form. These workers did not find the cis form in the liver unless high doses (12,000 IU) were fed. They argue therefore that the low activity of the isomers is not due to lower absorption but to losses occurring during the conversion step.

Also vitamin A acid has been shown to have biological activity (6, 7), although it does not appear to be converted to vitamin A in the organism.

A more basic approach to the mechanism of vitamin A action is represented by the researches being carried out already for a long time at the cellular, and lately also at the enzymic level. Pelc and Fell (8) recently studied, by means of autoradiography, the uptake of labelled aminoacids in the skin of chicks in both normal and hyper-vitaminotic media. These Authors concluded that vitamin A by inhibiting keratinization, decreases the uptake of tyrosine and cystine. The same Authors, by experiments with S-35 found that the basal cells of the normal epithelium have a mechanism for the synthesis of mucopolysaccharides which is blocked by keratinization.

An interesting suggestion which derives from the action of excessive doses of vitamin A on epithelia has been put forward by Laschet et al. (9). Finding that the most detrimental effect of high doses of vitamin A on fertility in the rat was obtained when the vitamin was administered at the time of mating, they suggest that changes in the uterine epithelium interfere with implantation.

Recent research at the enzymatic level has shown a relationship between vitamin A status and the activity of certain respiratory enzymes: the dehydrogenase part of the succinoxidase system was impaired in the liver and kidney of hypervitaminotic rats (10) while in vitamin A deficiency cytochrome reductase activity was considerably reduced (11). The biological oxidation of pregnenolone to progesterone in the intact animal has also been demonstrated to be dependent on vitamin A (12). In the deficient animal there is a complete loss of glyconeogenesis, resulting from the partial impairment of adrenal hormone production (13).

The conversion of carotene to vitamin A has been known for some years to occur mainly in the intestinal wall. It has now been demonstrated *in vitro* (14) in the liver and intestine (15) of chicks and, by Japanese workers (16) in the same organs of rats rabbits and frogs. The latter workers have isolated from the incubates, by paper chromatography,  $\beta$ -ionone and a vitamin A aldehyde-protein complex. This finding if confirmed, should provide support for the degradation theory of Glover and Redfearn (17) which is now generally accepted.

Sibbald and Hutcheson (18) deduce the existence of some intermediary product(s) from the fact that the conversion factor, defined by the Authors as

$$\frac{\text{mg carotene disappeared}}{\text{I. U. formed}} \text{ decreases with time.}$$

The *in vitro* demonstration of carotene conversion by the liver is the result of repeated efforts tending to show extra-intestinal conversion. However, vitamin A is formed from intravenously injected carotene even after hepatectomy (19), so that other organs must be involved as well, direct proof of which is still outstanding.

Moore and coworkers (20) found that the blood vitamin A level is higher in British men than in women while the opposite is true regarding carotene. This suggests a greater conversion efficiency in men than in women, a finding which may be related to the other well known sex difference of higher storage ability by animal females. The efficiency of conversion is different in the various species (100 % conversion in goats) and also in different breeds: lately Eaton and coworkers (21) have estimated it to be 1.4-1.8 times more efficient in Holstein than in Guernsey calves.

Whatever form of vitamin is fed, intestinal absorption of vitamin A always ends up with ester formation (22), but the question of whether higher (22) or lower (23) fatty acids are involved is being debated. This ester is found almost completely in the supernatant fraction of the homogenate from intestinal mucosa or muscle of rats or chickens while in guinea-pig the vitamin is more or less associated with all the cellular fractions (24). During absorption carotenoids are thrown out of fat solution and become associated with lipoproteins (23, 24). There probably are in the intestinal cells stereospecific lipoproteins capable of combining specifically with the carotenoid that can be absorbed, by the species, and so allowing its entry into the blood. Thus if lutein is given to chicks, the villi become yellow, otherwise remain almost colourless.

While vitamin A ester and carotenoids are associated in blood to lipoproteins, vitamin A alcohol is transported by association with  $\alpha_1$ -globulin (27).

As antioxidants are today normally added to chicken mashes and as a sparing action of some of them (DPPD and Santoquin) on vitamin A has been claimed, it has been proposed that these requirements should be assessed with reference to presence and nature of the antioxidants used (28). Certainly there is a point in this contention, I can only confirm (unpublished results) that DPPD does not increase vitamin A storage, in spite that by work done in our laboratory (29) DPPD has shown itself superior to BHT and gallate in the protection of both carotene and vitamin A from autoxidation. Of course the availability of the vitamin will be also a function of the stability of the preparations, and quite a lot of work has been done on the subject which presents the special difficulty of determining the vitamin in the presence of quite big amounts of its degradation products. To overcome this difficulty Budowsky (30) has developed a method based on the conversion of vitamin to anhydrovitamin A which is somewhat less sensitive than the Carr-Price method but far more specific.

From the point of view of stability the development of coated preparations has been a real turning point as the shelf life of the usual types (gelatine and wax coating) has become very large. Other factors come into play in the mash and therefore the final answer can only be had *in vivo*. As the result of an exhaustive research Branion and coworkers (31) came to the conclusion that gelatine preparations are superior to wax, or fat coated products. Results in our laboratory (unpublished) also tend to confirm this view. It should be pointed out, however, that even among preparations of a given type, consider-



able differences may be found with regards to availability due to different coating techniques, particle size, etc. Anyway too many interest are involved on this point and cannot be debated here. Ely (32) finds the wax coated preparation much more effective than the vitamin A palmitate absorbed on soy flour or carotene, a point on which I completely agree with him.

I was also glad to see that Kramer and Tarjan (33) too found that vitamin A storage is not directly related to the apparent digestibility of carotene, that crystalline carotene in oil has a lower biological value than carotene from natural sources and that the natural sources themselves are quite different in their activity, the three conclusions agreeing with our previous findings (34).

Among the other vitamins the one most strongly interrelated with vitamin A is certainly vitamin E, and recently the view has even put forward that the primary function on this vitamin would actually be to protect vitamin A (35). On this subject we shall soon hear from Prof. Dam. I would only like to mention that Sobel et al. (36) have found Vitamin E to double the storage of vitamin A both upon oral administration and local application. Still even vitamin E can have its noxious effect on vitamin A and there is new evidence that there are possibly optimum ratios for the intakes of vitamin A and E (37): high amounts (25 mg/lb live weight) of tocopherol lengthened the depletion time of calves given high amounts of vitamin A but reduced it if only small amounts were given (10  $\mu$ g/lb. live weight).

The fat and protein levels of the diet have also been repeatedly claimed to influence vitamin A utilization, but in opposite ways. Fat is generally thought to increase it, while high protein levels decrease liver storage in chickens (38) and cattle (39). I have found increased storage by addition of soybean oil or soap stock. On the other hand I have found the same storages with a 17 % and a 26 % protein level. Of course with the higher protein level growth was improved and similar storage in a bigger bird could be considered as a sign of decreased utilization.

To the list of factors that have been claimed to enhance vitamin A utilization, we can now add a new one: it is extractable with water from alfalfa and Ershoff (40) has shown it to stimulate growth of rats given sub-optimal amounts of vitamin A or to lengthen the survival time of rats on a deficient diet.

And in the end what can be expected from the continuous research that is being done? I do not think we can look for much improvement in the practical field. As I have said, stability of preparations is now quite satisfactory and requirements have already been fairly accurately estimated: any new estimate can not possibly be very different from the present accepted values. But for the more theoretical, and perhaps more important field of vitamin A action we can have the most hopeful expectations, as it is clear that even if the road is long, we are already approaching the final understanding of the fundamental mechanism which underlies the many phenomena we have discovered.

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## APPLICATION OF RECENT DEVELOPMENTS WITH FAT SOLUBLE VITAMINS

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Recent research with fat soluble vitamins has dealt primarily with the effects of various forms of vitamins A, E, and K on a variety of physiological and disease conditions occurring in the body, and to a lesser extent with quantitative requirements. Vitamin D has received very little attention and therefore will be omitted from this review.

### VITAMINS A AND K

The quantitative requirements of White Leghorn chicks and hens were reviewed by Scott *et al.* (1957). Chicks hatched from hens fed 1200 I. U. of vitamin A per pound of ration from a stabilized preparation required not more than 600 I. U. of vitamin A per pound of feed for maximum growth and the prevention of ataxia. The egg production and hatchability of adult birds was not improved by levels of stabilized vitamin A higher than 1200 I. U. per pound, nor by the addition of the antioxidant, DPPD. These workers also observed that the incidence of blood spots was greatest in eggs from hens fed 800 I. U. vitamin A per pound, and that 1200 and 1600 I. U. vitamin A per pound appeared to give maximum protection against blood spot incidence. Bearnse and associates (1960) have also observed that blood spot incidence in eggs was increased at levels of vitamin A below 1100 U. S. P. per pound, and that minimum blood spot incidence was achieved with from 1200 to 1600 units per pound. No further reduction occurred with vitamin A levels

up to 15,000 I. U. units per pound. Very recently, Stoewsand and Scott (1960) have reported an interrelationship between vitamin A requirement and protein level in the chick diet in which earliest deficiency symptoms and mortality were with the highest level of protein combined with the lowest level of vitamin A. No mortality or ataxia occurred at any of the protein levels when the chicks received 2400 U. S. P. units of vitamin A per pound of diet. High blood levels of uric acid *per se* were not responsible for the ataxia of vitamin A deficiency.

An extremely interesting report by Erasmus and associates (1960) indicates that stabilized vitamin A can aid markedly in the remission of symptoms of coccidiosis in young chicks. Stabilized vitamin A at a level of 800 I. U. per pound of feed was adequate for growth under normal conditions, but failed to support either growth or livability to the same extent as 8000 I. U. per pound after the chicks were infected with coccidiosis. The reported reduction in mortality confirms the earlier observations of Jungherr (1945). Waldroup *et al.* (1960) found that increased amounts of vitamin K supplied as Menadione Sodium Bisulfite Complex (Klotogen<sup>®</sup>F) markedly reduced both mortality and morbidity in chicks suffering from coccidiosis. Worthy of mention also is the frequently repeated field observation that adding 10,000 to 12,000 I. U. of vitamin A per pound of feed affords marked protection for chickens suffering from an infestation of capillaria worms. Adequate proof of the extent of this protection, or the means by which vitamin A ameliorates the damaging effects of coccidiosis or capillaria worms, is totally lacking.

Earlier workers, such as Almquist *et al.* (1938) and Rubin and Bird and Bird (1941), reported that carotene is as efficient as vitamin A from the standpoint of supporting growth. Erasmus *et al.* (1960) found, however, that 800 units of stabilized vitamin A per pound maintained growth and feed consumption as effectively in chicks infected with coccidiosis as 2400 units of vitamin A from pure beta-carotene and almost as effectively as 8000 units of vitamin A from beta-carotene. Ely (1959) has also reported that a vitamin A product stabilized with wax was much more effective in promoting the liver storage of vitamin A than either alfalfa meal, fish oil, or vitamin A palmitate in oil, although growth was essentially equal on all four materials. Wilkening *et al.* (1960) studied the effectiveness and stability during storage of two gelatin stabilized and one wax stabilized vitamin A products. On the basis of growth, feed conversion, and liver storage, they concluded that, although all three materials gave comparable results before storage, the two gelatin stabilized products were superior after storage. The relatively poor performance of provitamin A in some of these studies has not been explained. Sibbald and Hutcheson (1960) have shown that pure beta-carotene is converted rapidly to vitamin A in the chicken. They calculated that the amount of beta-carotene required to produce one I. U. of vitamin A was 0.383 micrograms plus or minus 0.685 micrograms, which is not statistically different from the widely used value of 0.6 micrograms, although the standard deviation was very large. Williams *et al.* (1960) have reported that Santoquin improved the retention of carotene in both alfalfa meal and complete diets stored under similar conditions, but that BHT was without effect. It would appear, however, that with the possible exception of growth, vitamin A products protected with an antioxidant and a coating of either gelatin or wax show not only greater stability, but also a higher biological effectiveness than either



unprotected vitamin A or the provitamins A from plants. It is also apparent that, under conditions of stress and disease such as are frequently encountered in practical production, the amount of vitamin A and possibly other vitamins required to support maximum growth and minimum mortality, may be several times greater than the amount required by healthy birds under laboratory conditions.

Although the degree of pigmentation in egg yolks and the skin of meat chickens has little or no nutritional implication, it does have a definite effect on consumer acceptability of the product. A relatively lightly pigmented product can be obtained by omitting carotenoid pigment-bearing ingredients, such as yellow corn and alfalfa meal from the diet, but a strongly pigmented product is frequently more difficult to obtain. Bunnell and associates (1960) have reported that beta-apo-8'-carotenal imparts a deep yellow color to the yolk. The addition of as little as four grams of a dry stabilized form of this compound per ton of feed was sufficient to provide adequate yolk color. Of interest also is the report by Griminger and Fisher (1960) that menadione (2-methyl-1,4-naphthaquinone) at the relatively high level of five grams per kilogram of diet has a marked pigment-enhancing effect in young chickens.

## VITAMIN E

The series of studies on vitamin E deficiency conducted at the National Institutes of Health have been extended by Bieri *et al.* (1960), who report normal growth and development of female chickens without dietary vitamin E or other antioxidants. Although many practical studies have shown that an adequate dietary source of vitamin E is required by chicks, research with purified diets by Dam (1944) and Zacharias *et al.* (1950) indicate that, under some conditions, no vitamin E is required. Utilizing the knowledge that selenium can replace alpha-tocopherol in the prevention of exudative diathesis (Patterson *et al.* 1957, Schwartz *et al.* 1957), and that sulfa amino acids can partially replace alpha-tocopherol in the prevention of muscular dystrophy in the chick (Dam *et al.* 1952), Bieri and associates (1960) proceeded to rear female New Hampshire chickens to maturity on a purified vitamin E-free diet, both with and without the addition of 4 per cent vitamin E-free lard. Growth and development were similar in both groups, and egg production began during the nineteenth week. Fertile eggs were obtained following artificial insemination but, because of incubation difficulties, no chicks were hatched. Blood samples revealed no differences in hematocrit, hemoglobin, or electrophoretic patterns between the two groups. Studies on tissue tocopherols indicated that the 2 to 5 mcg. per gram of tissue of apparent tocopherol residual in chickens on vitamin E-low diets (Bunnell 1956, and Pollard and Bieri 1959) is actually interfering material. After seven weeks of depletion time, tissue tocopherol was always zero, and the eggs produced by the tocopherol-free hens contained no detectable tocopherol. These studies certainly suggest that, under certain conditions, female chickens fed purified diets do not require vitamin E in the diet, and that the principal role of tocopherol is that of a biological antioxidant. More work is necessary, however, to study the development of the male chickens on a vitamin E-free diet and to carry this work through successive generations. The reports of Pollard and

Bieri (1959), apparently eliminating tocopherol from any vital role in an enzyme system in heart muscle, and Draper (1959), who concluded that the vitamin E requirement of rabbits for the prevention of muscular dystrophy represents a need for a suitable antioxigetic compound, further strengthens the evidence that the principal role and possibly the only role of vitamin E in metabolism is that of a biological antioxidant. Although Ames and Swanson (1958) failed to obtain a growth response from the antioxidant, Santoquin, Gordon and Machlin (1960) have reported that, in the presence of vitamin E-free fats, Santoquin promoted growth and improved feed efficiency to a greater extent than did d, alpha-tocopheryl acetate.

Several reports have contributed to a more precise understanding of the development of encephalomalacia in young chicks. Century and Horwitt (1960), utilizing vitamin E-low fats and oils and vitamin E-deficient chicks, found that encephalomalacia may be induced when linoleic acid is above 14 grams per kilogram of diet. The incidence of encephalomalacia was enhanced, however, by lauric and myristic acids, not affected by other fatty acids, and inhibited by oleic acid. Thus the intake of linoleic acid is a primary factor, while other fatty acids secondarily increase or decrease its effect. Machlin and Gordon (1960) also concluded that linoleic acid was the principal cause of encephalomalacia and that other unsaturated fatty acids, such as arachidonic, were also implicated. Linolenic acid was not involved. Kokatnur *et al.* (1960) report that possible oxidation products of long chain unsaturated fatty acids accelerate the appearance of encephalomalacia when stripped corn oil was also in the diet.

The relatively poor availability of the tocopherol in alfalfa to chicks has been studied further by Pudelskiewicz and Matterson (1960). Confirming earlier reports, they found the d, alpha-tocopherol in alfalfa to be only one third available to the chick, and that a compound (S) in hot ethanol extract of alfalfa acted antagonistically to tocopherol, increasing its excretion. When the vitamin E of alfalfa was separated from the rest of the meal, it was fully available. The addition of pure d, alpha-tocopherol to a tocopherol-low extract of alfalfa resulted in an excretion of tocopherol to the same extent as when alfalfa was fed.

The role of selenium in nutrition has been explored still further by Oldfield *et al.* (1960), who report that selenium given prenatally per os to ewes, or postnatally by injection to lambs, prevented white muscle disease and increased growth. The largest growth response came from the prenatal treatment. Massive doses of vitamin E administered at birth prevented white muscle disease but gave no growth response, suggesting an essential role for selenium in the growth of lambs. In contrast, Creger *et al.* (1960) reported that the addition of 0.1 parts per million of selenium to a vitamin E-low turkey breeder diet failed to improve egg production, per cent fertility, or per cent hatchability. Additions of vitamin E, however, gave a marked response in hatchability.

One of the practical problems in the widespread usage of vitamin E assay methods has been the fact that they were cumbersome and expensive, and frequently failed to differentiate between the biologically active tocopherols and the inactive tocopherols and tocopherol-like compounds. Bunnell (1957) reported that the tocopherol stores in the liver of the chick varied linearly with the intake of alpha-tocopherol and, based on this fact, Pudelskiewicz



*et al.* (1960) have developed a chick assay method for evaluating biopotency. They found that d, alpha-tocopheryl acetate was 1.34 times more potent than dl, alpha-tocopheryl acetate, as measured by liver tocopherol content, and that d, or dl, alpha-tocopherol were utilized equally as well as their respective acetate esters. A shorter and equally accurate bioassay method has been tested by Dicks and Matterson (1960). They found that the two-week liver storage bioassay reported by Pudelkiewicz *et al.* (1960) can be shortened to a three-day supplementation period, and that dose response studies showed liver storage to be linearly related to intake. Relative biopotencies of various forms of alpha-tocopherol were similar to those obtained by the longer bioassay. Dicks and Matterson (1960) have also studied a simplified tocopherol assay method utilizing purification of the hot ethanol extract by saponification and chromatography through a specially prepared secondary magnesium phosphate column, instead of molecular distillation. The two methods gave essentially the same results, with equal precision for tocopherol determination on chick livers. Unfortunately, however, the simplified method proved to be nearly as much work as the molecular distillation, and therefore offers little advantage for routine tocopherol determination.

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## ROLE OF SELENIUM AND VITAMIN E IN NUTRITION

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Selenium has long been known to be a highly toxic element. In certain areas selenium is present in toxic amounts in forage and grain. More recently it has been found that selenium has an important role in nutrition and, under certain conditions, becomes an essential element.

The research on the role of selenium in nutrition began with the observation by Schwarz in Germany (1) that liver necrosis developed in rats receiving diets containing large amounts of yeast or diets containing casein (2). This could be prevented by the addition of either vitamin E or cystine. However, when these experiments were repeated in the United States, Schwarz (3) found that most American yeasts, in contrast to European yeasts, did not produce liver necrosis and that American purified casein actually prevented liver necrosis when added to a necrogenic diet.

Torula yeast, which is grown on sulfite liquor from the paper industry, produced liver necrosis in the same manner as European Brewer's yeast. American Brewer's yeast was also found to prevent liver necrosis when added to a torula yeast diet, and therefore, contained a protective factor. This was shown by Schwarz (4) to be water soluble and did not contain sufficient vitamin E or cystine to account for its activity. This unidentified factor was then designated Factor 3, because it was the third type of compound in addition to vitamin E or cystine that would prevent this nutritional disorder.

When these necrogenic torula yeast diets were fed to chicks, Scott, et al. (5), found exudative diathesis but no liver necrosis. This exudative diathesis which could be prevented by vitamin E, was similar to that observed

by Dam (6) on a vitamin E free diet containing 5 % or more of cod liver oil. Scott, et al. (5), also found that Brewer's yeast, which is essentially free of E, also prevented exudative diathesis in chicks. This suggested that the factor which prevented exudative diathesis in chicks was similar to Factor 3 which prevents liver necrosis in rats.

In our studies on the nature of this factor which occurred in kidney, we found that it was water soluble and that it was destroyed by ashing in the presence of acid but was stable to alkaline ashing. This suggested the presence of an element which formed a volatile acid and a non-volatile salt. Among the elements which have this property are sulfur, selenium, arsenic and tellurium. Selenium, in the form of the selenite salt proved to be active at 0.1 ppm in the diet (7). Schwartz (8) identified selenium in the highly active concentrates of Factor 3 and showed the activity of selenium as selenite in the prevention of liver necrosis in rats.

### SELENIUM DEFICIENCY IN CHICKS

A deficiency of selenium in chicks reduces growth, produces exudative diathesis and increases mortality (Table 1). About 0.1 ppm of selenium is required for growth and prevention of exudative diathesis. A comparison of the activity of selenium as selenite with the activity of kidney hydrolysate shows that the activity of the kidney can be accounted for on the basis of its selenium content.

TABLE I  
EFFECT OF SELENIUM AND KIDNEY HYDROLYSATE ON THE PREVENTION OF  
EXUDATIVE DIATHESIS

| 11 Chicks per Group                 | 13 Days Depletion                             |                              |
|-------------------------------------|-----------------------------------------------|------------------------------|
| Supplement<br>per Kg of Diet        | Wt. at 24<br>Days and<br>Survivors ( )<br>Gm. | Incidence<br>Ex. Diath.<br>% |
| None                                | 190 (6)                                       | 91                           |
| .05 mg Selenium (Selenite)          | 212 (10)                                      | 27                           |
| .10 mg Selenium (Selenite)          | 211 (11)                                      | 0                            |
| .25 mg Selenium (Selenite)          | 230 (10)                                      | 9                            |
| .50 mg Selenium (Selenite)          | 218 (11)                                      | 0                            |
| 10 mg Hydrolyzed kidney (.03 mg Se) | 202 (8)                                       | 30                           |
| 15 gm Hydrolyzed kidney (.05 mg Se) | 230 (10)                                      | 10                           |
| 30 mg Hydrolyzed kidney (.10 mg Se) | 245 (11)                                      | 0                            |

It has been reported (9) that torula yeast accentuates exudative diathesis when added to a soy protein diet which otherwise produces little or no exudative diathesis. This has been shown to be partly due to the inorganic component of torula yeast by Bieri (9) and partly due to the unsaturated fatty acids which may be present in torula yeast (10).



The action of the unsaturated fatty acid on exudative diathesis is shown in Table 2 in which we compared the effects of torula yeast and methyl linoleate on the incidence of exudative diathesis. It can be seen that 100 grams of torula yeast which contributed 2 grams of linoleic acid per kg of diet, produced the same incidence of exudative diathesis as 10 grams of methyl linoleate. The addition of selenium prevented the exudative diathesis which had been induced by the methyl linoleate and also reduced the peroxide content of the liver. Selenium thus appears to be effective in counteracting the prooxidant effect of unsaturated fatty acids.

TABLE II

EFFECT OF UNSATURATED FATTY ACID ON EXUDATIVE DIATHESIS AND LIVER PEROXIDES

| Basal diet — 30 % soya protein<br>+ 2.5 % vitamin E free lard |                                      |                                 |                             | 12 chicks/group |
|---------------------------------------------------------------|--------------------------------------|---------------------------------|-----------------------------|-----------------|
| Supplement<br>per Kg of Diet                                  | Linoleic<br>Acid<br>in Diet<br>gm/kg | No. birds<br>with<br>Ex. Diath. | Liver<br>Peroxide<br>Values |                 |
| None                                                          | 3                                    | 1                               | .515                        |                 |
| 100 gm Torula yeast                                           | 5                                    | 5                               | —                           |                 |
| 2.5 gm Methyl linoleate                                       | 5.5                                  | 0                               | —                           |                 |
| 5.0 gm Methyl linoleate                                       | 8                                    | 1                               | —                           |                 |
| 10.0 gm Methyl linoleate                                      | 13                                   | 4                               | .62                         |                 |
| 10.0 gm Methyl linoleate<br>+ 1 mg Selenium                   | 13                                   | 0                               | .140                        |                 |

Selenium is also effective in preventing muscle dystrophy in chicks which develops on vitamin E free diets containing low amounts of protein (15 % casein, 10 % gelatin). On such a diet, muscle dystrophy may be prevented by either methionine, tocopherol or by 5 ppm of selenium. The lower levels of selenium (0.2 ppm) which are effective in preventing exudative diathesis are ineffective in preventing muscle dystrophy.

### SELENIUM DEFICIENCY IN PIGS

Pigs develop liver necrosis on a diet containing 40 % torula yeast. This can be prevented by feeding either tocopheryl acetate (40 ppm) or 0.5 ppm selenium as selenite (11).

The effect of these two supplements when added to a diet containing 40 % torula yeast as the sole source of protein is presented in Table 3.

The results show that although selenium and vitamin E prevented liver necrosis, it did not increase growth rate.

It thus appears that selenium-deficient pigs grow at a normal rate until they die suddenly of liver necrosis with very little preceding evidence of

TABLE III

EFFECT OF SELENIUM AND VITAMIN E ON GROWTH  
SURVIVAL AND LIVER NECROSIS IN PIGS

| Supplement                                                      | No.<br>Animals | Wt. and Survivors |                   | Pigs Dying<br>with<br>Necrosis |
|-----------------------------------------------------------------|----------------|-------------------|-------------------|--------------------------------|
|                                                                 |                | 4 Weeks           | 8 Weeks           |                                |
| None                                                            | 4              | 12.6 <sup>4</sup> | 27.5 <sup>2</sup> | 2                              |
| 1 ppm Se as Selenite                                            | 4              | 12.3 <sup>4</sup> | 26.4 <sup>4</sup> | 0                              |
| 40 ppm tocopherol acetate                                       | 3              | 11.9 <sup>3</sup> | 27.0 <sup>3</sup> | 0                              |
| Survival Times of Pigs Dying with Liver Necrosis — 33, 34 Days. |                |                   |                   |                                |

illness. Autopsy of pigs dying (Slide 4) on the basal diet revealed liver necrosis, yellow fat, edema and hemorrhage in the lymph nodes, intestines, heart and skeletal muscles. There was also a thick yellow gelatinous exudate which appeared subcutaneously and in the visceral cavity. (Slide 5 — Necrotic Liver) (Slide 6 — Normal Liver) (Slide 7 — Autopsy) (Slide 8 — Yellow Fat)

This liver necrosis appears to be the same as that described by Anna Lisa Obel (12) and as that which occurs spontaneously in the field in Sweden.

Spontaneous liver necrosis has a high incidence in Sweden and has been found in about 10 % of all pigs autopsied in diagnostic work (12). It also occurs in Germany and England although not to such a high incidence as in Sweden. This author also produced this disease experimentally and prevented it by the addition of vitamin E.

## SELENIUM DEFICIENCY IN SHEEP

Stiff lamb disease in sheep and white muscle disease (WMD) in calves have long been observed in many parts of the world. Although vitamin E was reported to prevent the muscle dystrophy in sheep (13) it soon became apparent that other factors besides vitamin E were involved. The use of vitamin E was not always successful (14) and the lack of correlation between tocopherol blood levels and the incidence of stiff lamb disease pointed toward the involvement of other factors. Stiff lamb disease also occurred on good alfalfa pasture which was rich in vitamin E. Hogue, et al. (15), reported that a supplement containing wheat bran and linseed meal which was effective in preventing stiff lamb disease contained a factor which prevented exudative diathesis in chicks and which was not tocopherol. Subsequently, Muth, et al. (16), and Proctor, et al. (17), showed that selenium (as selenite) was effective in preventing the development of stiff lamb disease. Proctor (17) also found that those supplements such as linseed meal which were effective in preventing both white muscle disease in sheep and exudative diathesis in chicks were rich in selenium. McLean, et al. (18), in New Zealand, reported that selenium gave growth responses of 12 to 40 percent in lambs which had



come from farms with a history of «ill thrift.» (Slide 9) The selenium was given both as selenite and selenate at levels of 1.0 mg and 0.5 mg respectively by both parenteral and oral routes at 10-day intervals. The greatest response to selenium was observed on those groups of lambs which were the most severely affected with WMD. However, a growth response of 23 % was also obtained on a farm where WMD was extremely rare. Drake, Grant and Hartley in New Zealand have also observed marked growth responses to selenium some of which are shown in Slide 10.

There is evidence that although vitamin E may prevent WMD it does not replace the selenium required for growth. Oldfield, et al. (19), found that supplementation of lambs with 200 units of tocopherol acetate given orally prevented WMD but had no effect on growth. (Slide 11) The injection of a total of 1.4 mg of selenium (as selenite) at 1 and 14 days into the lambs, prevented WMD and gave a 35 % growth response over the basal. The addition of 0.1 ppm of selenium to the diet of the ewes prevented WMD and gave a growth response of 78 % over the basal. This suggests that selenium is essential for prenatal development and, that, although selenium given post-natally will prevent WMD, it does not completely overcome the growth retardation produced by prenatal selenium deficiency.

## FACTORS AFFECTING INCIDENCE OF SELENIUM DEFICIENCY

Stiff lamb disease in the Western United States, occurs mainly in irrigated areas, especially where gypsum is applied to the soil. Lakin (20) has reported that continued irrigation leaches out the selenium in the soil and cited an instance in Israel where the selenium content of the soil was high and the alfalfa grown on it contained 40 ppm of selenium. After continued irrigation there was no detectable selenium in the plants.

The availability of selenium in plants and feed may also affect the incidence of WMD. Hogue, et al. (15), who used cull kidney beans in their basal diet to produce WMD in lambs, found that cooking kidney beans greatly reduced the incidence of still lamb disease. Swingle (21) studied the selenium content of pastures in Oregon, Idaho and Montana. He found that, although the forage in the areas which produced WMD had a lower selenium content in general than those areas which were free of WMD, there was a great deal of overlapping. Thus, some pastures in WMD-producing areas had higher selenium contents than pastures in other areas which were free of this disease. He also found two samples of hay, one of which produced 70 % incidence of WMD and the other produced no WMD. Both had the same selenium content. This shows that other factors than selenium may affect the incidence of stiff lamb disease.

The drying of skim milk powder also affects the availability of selenium in the milk. Fink (22) found that rats on diets containing fresh skim milk did not develop necrosis while those on roller-dried milk developed 76 % liver necrosis and those on spray-dried milk developed 40 % necrosis (23). Thus liver necrosis occurring on dried milk could be prevented by the addition of 0.4 µg of selenium (as selenite) per day. Thus the drying of milk either reduces the availability of selenium or some other factor which prevents liver necrosis.

# COMPARISON OF EFFECT OF SELENIUM, TOCOPHEROL, AND ANTIOXIDANTS ON VARIOUS SYMPTOMS OF VITAMIN E DEFICIENCY

A deficiency of vitamin E has produced a variety of lesions in many species. Table 4 is a summary of the effect of either vitamin E, antioxidants or selenium in preventing these lesions.

TABLE IV

COMPARISON OF ACTIVITIES OF SELENIUM AND VITAMIN E AND ANTIOXIDANTS

| Deficiency Symptoms                                                         | Vitamin E | Antioxidants | Selenium |
|-----------------------------------------------------------------------------|-----------|--------------|----------|
| <b>RAT</b>                                                                  |           |              |          |
| Resorption sterility                                                        | +(32)     | +(29)        | —(31)    |
| Liver necrosis                                                              | +(2)      | +(47)        | +(10)    |
| Peroxide formation in fat on feeding cod liver oil                          | +(39)     | +(34)        | —(30)    |
| Depigmentation of incisors                                                  | +(40)     | +(36)        | —(30)    |
| Brown coloration of uterus                                                  | +(33)     | +(36)        | —(30)    |
| Red cell hemolysis                                                          | +(37)     | +(35)        | —(30)    |
| Increase of Vit. A in liver                                                 | +(37)     | +(37)        | —(30)    |
| <b>RABBIT</b>                                                               |           |              |          |
| Muscle dystrophy                                                            | +(41)     |              | —(41)    |
| <b>SHEEP</b>                                                                |           |              |          |
| Muscle dystrophy                                                            | +(15)     |              | +(18,19) |
| Growth depression                                                           | —(23)     |              | +(23)    |
| <b>CALVES</b>                                                               |           |              |          |
| White muscle disease                                                        | +(52)     |              | +(42)    |
| Growth depression                                                           |           |              | +(51)    |
| <b>CHICK</b>                                                                |           |              |          |
| Encephalomalacia                                                            | +(43)     | +(44)        | —(45)    |
| Exudative diathesis                                                         | +(6)      | ±(44)        | +(7,9)   |
| Muscle dystrophy                                                            | +(28)     | +(28)        | ±(48)    |
| Blood albumin formation                                                     | +(46)     |              | +(46)    |
| <b>MICE</b>                                                                 |           |              |          |
| Necrosis of heart, liver, kidney, peripheral muscle, pancreatic atrophy     | +(50)     |              | +(50)    |
| <b>PIG</b>                                                                  |           |              |          |
| Liver necrosis, muscle dystrophy, hemorrhage in intestine, heart and muscle | +(13)     |              | +(13)    |
| Yellow fat due to feeding torula yeast                                      | +(13)     |              | +(13)    |
| Yellow fat due to feeding cod liver oil                                     | +(49)     |              | —(49)    |
| ( ) Reference Numbers                                                       |           |              |          |



## SUMMARY

1. Selenium can replace vitamin E in the prevention of exudative diathesis in the chick; of muscle dystrophy in pigs, chicks, sheep and rats and of liver necrosis in rats and pigs.
2. Selenium will not replace vitamin E for prevention of encephalomalacia in chicks; muscle dystrophy in rabbits and of resorption sterility in rats.
3. Selenium is more effective than vitamin E in promoting growth and preventing muscle dystrophy in sheep.

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## WATER SOLUBLE VITAMINS

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The present state of development of the broiler and swine industries rests in large part on the use of synthetic water soluble vitamins. Before 1940, dairy and meat products formed the primary sources of riboflavin and vitamin B<sub>12</sub>. The rapid development of the poultry industry in the United States was based on the expanding availability of soybean meal, which, however, was deficient in these two water soluble vitamins. The amount of riboflavin currently produced illustrates the impossibility of supplying riboflavin by milk products. In 1959, 100,000 kg of riboflavin were used in the United States for supplementation of animal feed. If this amount were to have been derived from milk by-products alone, 60 billion liters of milk would have been required which is equal to our current milk production.

Since the water soluble vitamin requirements of swine were discussed in the symposium last year by Dr. R. W. Leucke, this review will deal primarily with the water soluble vitamin requirements of poultry. The water soluble requirements for chick growth are listed in Table 1 in the order of the approximate nutritional importance under commercial conditions.



TABLE I  
WATER SOLUBLE VITAMIN REQUIREMENTS FOR CHICK GROWTH  
AND FOR REPRODUCTION

| Vitamin              | Requirement<br>mg/kg |                 | Addition Required<br>to Practical Diets |
|----------------------|----------------------|-----------------|-----------------------------------------|
|                      | Chick<br>Growth      | Breeder<br>Hens |                                         |
| Thiamine             | 2.0                  | ?               | No                                      |
| Pyridoxine           | 2.0                  | 2.0             | No                                      |
| Biotin               | 0.1                  | ?               | No                                      |
| Folic acid           | 0.5                  | .35             | Sometimes                               |
| Pantothenic acid     | 10.0                 | 10.0            | »                                       |
| Niacin               | 24.0                 | ?               | »                                       |
| Vit. B <sub>12</sub> | 0.01                 | 0.005           | Yes                                     |
| Riboflavin           | 3.0                  | 4.0             | Yes                                     |

### RIBOFLAVIN

The riboflavin requirements for starting chicks (0-8 weeks) is 3.0 mg/kg; for growing chickens, it is 2.0 mg/kg; for hatchability, it is 4.0 mg/kg and for egg production, it is 2.2 mg/kg. An example of riboflavin deficiency in the chick is shown in Slide 2. This shows the typical curled toe which develops in riboflavin deficiency and which may be used to recognize this deficiency.

### PANTOTHENIC ACID

A deficiency of pantothenic acid in the chick decreases growth, induces poor feathering and produces dermatitis around the eyes and the corners of the mouth. The requirement for pantothenic acid is 10-14 mg/kg on a purified diet. The pantothenic acid requirements can be modified by other components in the diet. For example, Yacowitz, et al. (1), has shown that the requirement of pantothenic acid is increased at low levels of vitamin B<sub>12</sub>. (Slide 4) These workers also found that the requirement for prevention of dermatitis and maintenance of good feathering is higher than that for growth. Under average conditions the cereal and soybean in the diet supply adequate amounts of pantothenic acid, but chicks on commercial type diets have been found to have the lesions typical of pantothenic acid deficiency.

### NIACIN

Niacin deficiency may occur on commercial type diets. The National Research Council recommended level for niacin for young chicks is 25 mg/kg. Higher levels may be required for other species. Thus Scott (2) found that turkeys required 50 mg/kg for growth and 70 mg/kg to prevent the enlarged hock disorder. He also found that the requirement for niacin for the

prevention of hock disorder was increased by the addition of cod liver oil. (Slide 5)

Similar results have been obtained by Heuser and Scott (3) (Slide 6) with ducks where the requirement for prevention of bowed legs (55 mg/kg) was greater than that for growth (45 mg/kg). They also found that while the niacin in yeast was effective in prevention of leg disorder, the niacin in wheat middlings was relatively inactive. This is similar to the results of Kodicek, et al. (4), who found that the niacin in corn is largely in a form which is microbiologically inactive and which is biologically unavailable to pigs, rats and chicks. Thus the analysis of a ration containing a large proportion of its niacin as corn products may not give a true measure of its biological effectiveness.

### FOLIC ACID

Folic acid is a component of many enzyme systems concerned with the synthesis of purines and pyrimidines in nucleic acids and therefore, it is essential for cell multiplication. A deficiency of it reduces growth, produces poor feathering and causes a reduction in red cells and hemoglobin formation. In the chick there are no specific symptoms which may be used to recognize a deficiency of this vitamin.

In the turkey (5) and the gosling (6) folic acid deficiency also produces cervical paralysis (Slide 7) which may be used to recognize this vitamin deficiency.

The folic acid requirement for the chick is 0.5 mg/kg and that of the turkey is 0.8 mg/kg.

The folic acid content of various feedstuffs are shown in Table 2. It can be seen from this that cereals are very low but that cereal byproducts, alfalfa meal and soybean meal are high. 30 % soybean meal in a ration will contribute 1.2 mg of folic acid per kg of ration which should meet the growth requirement of the chick and the turkey. However, cervical paralysis in turkeys has been observed on a practical type diet containing corn, wheat by-products and 15 % soybean meal (5).

TABLE II

FOLIC ACID AND VITAMIN B ANALYSIS OF FEEDSTUFFS

| Material             | Micrograms per Gram |                      |
|----------------------|---------------------|----------------------|
|                      | Folic Acid          | Vit. B <sup>12</sup> |
| Alfalfa Meal         | 3.6                 | 0                    |
| Corn                 | 0.1                 | 0                    |
| Wheat                | 0.2                 | .001                 |
| Wheat bran           | 1.0                 |                      |
| Skim milk powder     | 0.3                 | .04                  |
| Soybean meal         | 2.1                 | .002                 |
| Dried brewer's yeast | 13.6                | .001                 |
| Meat meal            | 0.7                 | .1                   |
| Fish meal            | .3 — 1.0            | .2                   |
| Sewage sludge        |                     | 5.0                  |



Rations containing fish meal as the protein source may also be deficient in folic acid. Although fish meal, which is laboratory dried at low temperature may contain *ca* 4 ppm of folic acid, fish meal, which is dried at high temperatures may contain less than one-tenth this amount because most of the folic acid deficiency may result on a commercial type diet containing fish meal (7) (8). This has been shown in experiments at Vancouver and at Washington State College.

### VITAMIN B<sub>12</sub>

Vitamin B<sub>12</sub> is the only vitamin that is not formed by plants and its ultimate source is bacterial or fungal fermentation. Vitamin B<sub>12</sub>, like riboflavin, has been essential to the extensive use of vegetable protein supplements. The vitamin B<sub>12</sub> content of several foods is given in Table 2. The vitamin B<sub>12</sub> requirement for growth of the chick is 10 mcg/kg (9 mg/ton) of feed, and that for hatchability is 4 mcg/kg.

It may be interesting to compare the current cost of supplying B<sub>12</sub> by fermentation with that of formerly supplying it by animal or fish products. The current cost of vitamin B<sub>12</sub> for animal feed is 1.5¢ per milligram which corresponds to a cost of 15¢ for the 10 mg of B<sub>12</sub> used per ton of chick feed. This amount of vitamin B<sub>12</sub> is equivalent to that contained in *ca* 80 lb of fish meal. It is also interesting to compare the production of fermentation B<sub>12</sub> with that available in animal protein supplements. The present U. S. consumption of vitamin B<sub>12</sub> for animal feed is 300 kg per year. The current U. S. consumption of meal is 1,500,000 tons and, of fish meal, 300,000 tons, which corresponds to a total of 120 kg of vitamin B<sub>12</sub>. Thus the vitamin B<sub>12</sub> produced by fermentation is approximately 2.5 times that available in the form of animal protein.

The past year has seen an elucidation of the mechanism of action of vitamin B<sub>12</sub>. Vitamin B<sub>12</sub> has been found to have a role in the formation of nucleic acid and in the utilization of propionic acid. Stadtman, et al. (9), and Gurnany, et al. (10), have shown that vitamin B<sub>12</sub> is involved in the metabolism of propionic acid. In the utilization of propionic acid, it is first carboxylated to give methyl malonyl coenzyme A. This is then isomerized by a B<sub>12</sub>-containing enzyme to give succinic acid. Thus vitamin B<sub>12</sub> is essential to the utilization of propionic acid and explains the observation by Marsden (11) that cobalt deficient ruminants which are vitamin B<sub>12</sub> deficient have an impaired metabolism of propionic acid. This also explains the observation of Hartman (12) that high protein leads increased the requirement for vitamin B<sub>12</sub>. He found that certain amino acids would also increase the B<sub>12</sub> requirement and that those amino acids which increased vitamin B<sub>12</sub> requirements were those which would be metabolized in a manner similar to propionic acid. He also found that propionic acid (as the triglyceride) increased the vitamin B<sub>12</sub> requirement since it depressed growth in the absence but not in the presence of vitamin B<sub>12</sub>. Thus, there is an impaired utilization of propionic acid in the rat similar to that in ruminants.

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139. WHITEHILL, A. R., KISER, J. S. and STOKSTAD, E. L. R. «A study of the Effectiveness of Several Tetracyclines in Controlling an Experimental PPLO Infection in Chicks», *The Poultry Science Association, Meeting* August, 1960.

## DISCUSSION

*Dr. Kohn* (Scotland). We have heard the type of paper which we always expect from Dr. Stockstad. A man of his knowledge has given us a magnificent reasoned summary of the present position and he has illustrated it with magnificent slides. The paper is now open for discussion. I would recommend all speakers that they try to speak clearly, giving their names, their countries and the languages in which they will be speaking, and that they must, underline must, write down their remarks on the paper which is supplied and then deliver them here to the rostrum.

*Dr. Stockstad* (U. S. A.). I have heard a report, but I cannot remember who made the report, that they got a 25 % increase in the wool production when they gave salinium. I have also heard another report by somebody, I believe in Oregon, in which they were studying salinium toxicity in feed, and they said that if they would add a slightly toxic agent of salinium that they could get an increase in wool, or wool length. When you have salinium toxicity with animals, apparently the hair becomes long just before it falls out and by using a discreet level at a slightly toxic level they were able to get more wool than they got under normal conditions.

*Dr. Kohn* (Scotland). Any further contributions?

*Dr. Hansen*. Hansen, U. S. A., English. I just want to add this comment, that we also have studied salinium in pigs through a test conducted by Dr. Stockstad at the time they were working on this, and the interesting point of our observation, I think, is that I made a mistake in my calculation in adding salinium to the diet. It was totally yeast diet, instead of adding the tenth part of salinium which he suggested, we added .045 per million, and this level was sufficient to prevent all of the symptoms which we otherwise got with a total yeast diet, and we fed some of these pigs to 90 kilo slaughter weight before we killed them.

*Dr. Castellá*. For Spain it is very interesting to study plant toxicology

*Dr. Castellá* (Spain). For Spain it is very interesting to study plant toxicology such as *generus estragus* and you have described a great deal about the participation of salinium in the toxicology of the *estragus*. Have you solved this problem? Does salinium participate in the *estragus* or not?

*Dr. Stockstad* (U. S. A.). As I understood the question, have we studied the toxicity in *stragus*? Is that the question?

*Dr. Castellá* (Spain). Yes.

*Dr. Stockstad*. No, we have not studied this. I have seen some reports, in which they fed weeds which were high in salinium, to sheep, and made a salinium count of their tissues and if they were able to get up to 40 parts salinium in the kidney without observing any toxicological effects on the sheep. However, as you probably may have already seen, under certain conditions this *estragus* may contain up to one thousand parts of salinium and under distribution it would be highly toxic. As far as I know the salinium



in estragus has not been completely identified. May I correct myself? The chemical form of stragus has not been completely identified. It is present, however, in the form of remido acid which is propagated to 16 on the finding.

*Dr. Kohn.* I do not know what to admire more, the magnificent summary which Dr. Stockstad has presented, so well illustrated by slides and given with excellent bio-chemical logic, or the way in which, deferring to wishes which are imposed on us, he has been able to shorten his presentation. It is with very great reluctance that I must ask those many of us who would like to discuss this fascinating problem to reduce their remarks in time and number. The paper is open for discussion.

*Dr. McGinness (U. S. A.).* Dr. Stockstad, in your presentation you showed data indicating niasen to be required in turkeys for prevention of a type of leg abnormality. Did you clearly distinguish between the type of leg abnormality that we see in young turkeys and the type which we see in turkeys that are approaching maturity? I think this should be cleared up if you did not do that.

*Dr. Stockstad.* I was quoting the work of Scott at Cornell. Now I think that I would like to ask Dr. McGinness if he has developed anything on that because he has done a great deal more work in that field than I have. I would also like Dr. McGinness to comment on this pholic acid deficiency in fish meal on which he has done a great deal of work.

*Dr. McGinness.* Well, it has been our observation that niasen is required for the prevention of a type of peurosis or leg abnormality in turkeys that are 2, 3 or 4 weeks of age. Our results would indicate that niasen has no relation to the type of leg abnormality, weakness or enlargement, sometimes called enlarged hocks, that we find in turkeys that are approaching maturity. We have conducted a number of years work on this problem and niasen was found, at least under our conditions, to have no influence on the development of that condition. Now in relation to the pholic acid which Dr. Stockstad mentioned, I think there is a real possibility that when fish meal is depended on as the major source of supplementary protein in the diet and especially when the level of alfalfa is greatly reduced, there is a danger of encountering a deficiency. I would also add that when milo or sorgo is used in place of corn this danger might be even greater.

*Dr. Kohn.* Thank you Dr. McGinness. May I ask you to announce your names?

*Dr. Singsen.* Singsen, U. S. A. I should like to comment on one point and ask a question on another. Commenting first on the paper on salinium and Vitamin E, I should simply like to add, which Dr. Stockstad did not mention, that work this past year, presented this past summer at the Poultry Science Meeting, suggested that salinium does not replace recopherol in the fertility and hatchability role in the avian species. In this affect, the absence of effectiveness of the salinium is apparently the same as in the rat. The tocopherol is apparently the required material. My second point and a question to Dr. Stockstad, is specifically this. Should not the effect of niasen in preventing leg abnormalities or hock disorders in young turkeys or in chicks be re-examined in the light of the knowledge of the last two years about the role of zinc in these same leg abnormalities? Most of the work done with niasen and poline was done before there was any appreciation which we now understand of the effect of zinc in this same condition.

*Dr. Stockstad.* I would like to thank Dr. Singen for calling my attention to the fact that I neglected to state the ineffectiveness of salinium in the promotion of fertility in the chick. I think also that the suggestion that he has made regarding the reevaluation of the effect of niasen on leg disorders in chicks would be very good, in view of our recent knowledge on the role of zinc in this phenomenon. I think it is also interesting here to recall the slide that I gave on the effect of cod-liver oil on increasing the incidents of leg disorders in turkeys. In this case it was followed by multiple deficiency, or multiple effect, in which both limoney and niasen had an effect on the leg disorder in turkeys. I think that it is also possible that you can have an inter-relationship in the effect of niasen and zinc in the leg disorders of chicks.

*Dr. Kohn.* Thank you Dr. Stockstad. Any other?

*Dr. Hansen.* Hensen, U. S. A. I would like to ask Dr. Stockstad or anyone else who would care to answer, in view of the many papers from Britain on the problem of bound niasen, particularly in the cereals, should we assume that, thinking of swine now, not chicks, none of the cereals or their by-products have available niasen? Is that a fair assumption on the basis of the many papers in Britain that have been published during the last ten years?

*Dr. Stockstad.* I think it would be very presumptuous of me to answer a question on the availability of niasen in cereals, when much of this work has been done in the department of Dr. Kohn.

*Dr. Kohn.* If I may attempt to answer the question. I think that when it comes to corn, maize, I think that our experiments do directly confirm that nicotine acid is not available. The work done by Curiset with other cereals, with the rat and with the chick would support the contention that for the pig, the Vitamin at present is not available. But direct evidence, as far as we are concerned, is so far only available for corn.



# UNIDENTIFIED GROWTH FACTORS IN BROILER DIETS

BY

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A review of the literature reveals that research dealing with unidentified growth factors has been in progress in several University laboratories for over 30 years. During this time many supplements such as fish, milk, fermentation, green vegetable and other products have been shown to be sources of these factors. As time progressed many of the nutrients that produced a growth response such as the antibiotics, Vitamin B<sub>12</sub>, methionine, Zinc and others have been isolated, identified and are now being produced and distributed commercially. Although it is recognized that those nutrients producing the greatest (UGF) response have probably already been identified, most nutritionists are in agreement that the crude supplements still produce a response that can only be accounted for on the basis of unidentified factors.

There have been so many discoveries in poultry nutrition since the beginning of unidentified growth factor research that only the most recent reports will

be reviewed here. However, a number of excellent reports such as those by Scott and Zeigler (1960), Couch et al. (1960) and Bird (1958) cite references reviewing (UGF) research for those desiring more detail on the earlier work.

## CONCENTRATION, ISOLATION AND IDENTIFICATION OF NEW FACTORS

Considerable progress has been made recently on the isolation and identification of new factors. Couch and others (1960) reported the isolation of organic unidentified factors from corn distillers dried solubles, dried whey and fish products. Davis and Norris (1960) in their attempt to isolate the whey factor have shown that such products as recrystallized lactose and C P lactose each promoted growth. They postulated therefore that the whey factor is either absorbed by lactose or occluded on the crystals during growth. They further state that the factor is probably organic in nature. Wiese and Associates (1960) were able to concentrate the factor in dried egg yolk to a crude crystalline material containing approximately 70 % of the activity of the original material. From these reports it appears that considerable progress is being made in this field and that eventually these factors will be identified and produced synthetically or microbiologically for commercial use. It is conceivable that the use of new growth factors in practical diets may result in a greater growth response than attributable to the crude supplement they replace in that some feed supplements have been shown to supply both growth promoters and growth inhibitors.

## ZINC AS A GROWTH FACTOR

Among the recent research has been that of O'Dell and Associates (1958) who showed that the Zinc requirement of chicks on a purified diet containing soybean protein was approximately 35 mg. per kg. of diet. Additional calculations revealed that corn-soybean oil meal-fat-research diets and practical diets may be deficient in Zinc, with the result that commercial trace mineral producers and distributors have supplemented their trace mineral product to supply 20 to 40 parts per million of Zinc when used according to directions. These products have been accepted by the feed manufacturer and are being used in commercial diets with apparently satisfactory results. For the investigator using commercial feed supplements testing practical diets it does mean that some previous results require verification following this change.

## MASH VS. PELLETS

The use of mash versus the same feed pelleted in broiler diets constitutes a major growth and feed utilization factor. Commercial broiler feeders appear to have recognized this difference before the experiment station investigators, with the result that most feed companies are using pellets, exclusively based on the results from their own unpublished comparisons. At



an early date in pellet feeding Runnels and others (1957) fed mash to six pens of 150 broilers each to four weeks of age and then provided the same feed pelleted to the broilers in three of the pens. At eight weeks of age the straight run broilers receiving pellets averaged 2.91 pounds while those receiving mash averaged only 2.85 pounds. Feed utilization was also improved in that, those broilers receiving pellets required 2.10 pounds of feed per pound of broiler while the mash fed birds required 2.17 pounds of feed per pound of broiler. Approximately three and one-half years later Combs et al. (1960) in the same Del-Mar-Va area demonstrated the marked improvement over the earlier work by feeding three pens of 150 Pilch male broiler chicks mash and comparable groups feed from the same batch pelleted. The mash fed broilers averaged 3.33 pounds at eight weeks of age and required 2.11 pounds of feed per pound of broiler. The comparable groups receiving their feed pelleted averaged 3.64 pounds and required only 1.93 pounds of feed per pound of broiler. A number of reasons have been proposed that would explain the growth and feed utilization improvement attributable to pellets but as yet no conclusive evidence is available as to their specific effect.

## FATS AS A GROWTH FACTOR SOURCE

Fats are another feed supplement that have been shown to contain a growth factor. Carew and others (1959) and Isaacks et al. (1960) have demonstrated the presence of a (UGF) in soybean oil while Menge and Denton (1960) have shown that both lard and corn oil stimulate growth of chicks fed semisynthetic diets. Combs and Nicholson (1960) have shown fat added to a practical broiler diet at a 10 per cent level produced a growth response over the diet containing two and one-half per cent fat. This applied to hydrolyzed animal and vegetable fat, soybean oil and tallow. Of the three, the birds receiving the diet containing tallow were the heaviest. Sibbald et al. (1960) fed tallow and undegummed soybean oil alone and in combination as supplements to chick diets. They observed a greater growth response from the combination than to either fat alone. This information is of considerable practical value in that most commercial broiler feeds are supplemented with from two and one-half to ten per cent stabilized feed grade fat.

## FACTORS AFFECTING (UGF) RESPONSE

Under this heading the author desires to refer to the research of Fritz and co-workers (1960) and then present some original work that appears to have a bearing on this topic. Fritz and co-workers (loc. cit.) demonstrated that the use of antibiotics reduced the response to growth factor supplements from 10 per cent down to 3.3 per cent. They stated that a four-week feeding test period was most satisfactory and demonstrated that chicks on purified diets produce a greater growth response to (UGF) supplements than those on corn-soy-fat research diets. They state further that the use of purified diets made application of results to practical diets difficult.

There appear to be many interactions and limiting factors in (UGF) research. These situations make it difficult to determine just how much

response can be expected from these factors when they are available in a pure form, but the preliminary results indicate that the growth improvement will be considerable.

Simplified corn-soy-fat diets and practical diets are affected by deficiencies and improper balance. They are further handicapped by each new discovery in that the addition of a new nutrient to the basal diet may produce such an interaction as to make the previous research invalid and necessitate the verification of previous results before further progress can be made. In spite of these difficulties with corn-soy-fat diets, it appears that they are the closest approach to practical diets available to the investigator and that a continuation of research with both purified diets and corn-soy-fat diets is justified.

## EXPERIMENTAL PROCEDURE REPORT NO. 1

Six experiments were conducted in battery brooders with sexed White Rock cockerels. Each battery was stocked with ten chicks and each treatment was replicated three times. The chicks were from the same source for all experiments. The DL Methionine used as one of the treatments was from a commercial source while the incinerated chick ash was obtained from a gas incinerator used to burn the dead chickens from the autopsy laboratory. The white dry ash was sifted to remove the bones and it is considered that the fine ash used in these experiments came primarily from chicken and turkey tissue.

The negative control diets were composed primarily of supplemental corn-soybean oil meal and fat but were not the same in all experiments. This is not considered important in that the basal diet appears to have had little or no effect on the response to these variables. The analyses of these diets ranged from 20.0 to 20.3 per cent protein, 1.03 to 1.07 per cent calcium, .66 to .70 phosphorus and were calculated to supply 1003 to 1009 calories of productive energy per pound. All diets in each experiment were equated for protein, calcium, phosphorus and energy.

## RESULTS AND DISCUSSION REPORT NO. 1

The results from these six experiments have demonstrated a growth response attributable to both incinerated chicken ash and DL Methionine. The effect of the ash is thought to be due to some mineral other than calcium or phosphorus as the diets were equated for these minerals. The research is being continued to determine if minerals other than Zinc contributed to growth. DL Methionine has been confirmed as a growth factor. This effect has been demonstrated before by many investigators.

The response of the chicks and interpretation of the data appears to differ from some previous (UGF) research in that at four weeks of age the effect of ash and Methionine on growth was additive while at seven and ten weeks of age it tended to be synergistic. Their effect on feed utilization was additive at all ages.



TABLE I A

CHICK EXPERIMENT — 4 WEEK OF AGE

|                | Negative Control |             | + Inc. C. Ash* |               | + D L Methionine |               | + Ash + Methionine |               |
|----------------|------------------|-------------|----------------|---------------|------------------|---------------|--------------------|---------------|
|                | Ave. Wt.**       | Feed/Wt.*** | Ave. Wt.       | Feed/Wt.      | Ave. Wt.         | Feed/Wt.      | Ave. Wt.           | Feed/Wt.      |
| Experiment 1   | 1.12             | 1.78        | 1.16           | 1.82          | 1.11             | 1.71          | 1.21               | 1.65          |
| Experiment 2   | 1.08             | 1.80        | 1.14           | 1.77          | 1.16             | 1.68          | 1.18               | 1.66          |
| Experiment 3   | 1.09             | 1.82        | 1.13           | 1.79          | 1.12             | 1.73          | 1.18               | 1.72          |
| Experiment 4   | 1.10             | 1.82        | 1.16           | 1.79          | 1.15             | 1.73          | 1.19               | 1.70          |
| Experiment 5   | 1.13             | 1.84        | 1.11           | 1.79          | 1.13             | 1.71          | 1.17               | 1.68          |
| Experiment 6   | 1.10             | 1.80        | 1.17           | 1.78          | 1.15             | 1.71          | 1.19               | 1.68          |
| Average Change | 1.10             | 1.81        | 1.15<br>+ .05  | 1.79<br>— .02 | 1.14<br>+ .04    | 1.71<br>— .10 | 1.19<br>+ .09      | 1.68<br>— .13 |

\* Incinerated Chicken Ash.

\*\* Average weight in pounds. Each figure is the average of three pens of ten chicks each.

\*\*\* Feed/weight is the expression of the pounds of feed required to produce a pound of chicken.

TABLE I B

CHICK EXPERIMENT — 7 WEEKS OF AGE

|                | Negative Control |             | + Inc. C. Ash* |               | + D L Methionine |               | + Ash + Methionine |               |
|----------------|------------------|-------------|----------------|---------------|------------------|---------------|--------------------|---------------|
|                | Ave. Wt.**       | Feed/Wt.*** | Ave. Wt.       | Feed/Wt.      | Ave. Wt.         | Feed/Wt.      | Ave. Wt.           | Feed/Wt.      |
| Experiment 1   | 2.52             | 2.13        | 2.60           | 2.17          | 2.50             | 2.06          | 2.71               | 2.00          |
| Experiment 2   | 2.40             | 2.12        | 2.51           | 2.11          | 2.60             | 2.02          | 2.63               | 2.02          |
| Experiment 3   | 2.48             | 2.19        | 2.51           | 2.20          | 2.50             | 2.07          | 2.63               | 2.08          |
| Experiment 4   | 2.52             | 2.17        | 2.62           | 2.13          | 2.59             | 2.09          | 2.64               | 2.09          |
| Experiment 5   | 2.52             | 2.19        | 2.51           | 2.13          | 2.60             | 2.06          | 2.77               | 2.07          |
| Experiment 6   | 2.50             | 2.14        | 2.63           | 2.13          | 2.59             | 2.08          | 2.70               | 2.06          |
| Average Change | 2.49             | 2.16        | 2.56<br>+ .06  | 2.15<br>— .01 | 2.56<br>+ .06    | 2.06<br>— .10 | 2.68<br>+ .18      | 2.05<br>— .11 |

\* Incinerated Chicken Ash.

\*\* Average weight in pounds. Each figure is the average of three pens of ten chicks each.

\*\*\* Feed/weight is the expression of the pounds of feed required to produce a pound of chicken.

TABLE I C  
CHICK EXPERIMENT — 10 WEEKS OF AGE

|              | Negative Control |             | + Inc. C. Ash* |          | + D L Methionine |          | + Ash + Methionine |          |
|--------------|------------------|-------------|----------------|----------|------------------|----------|--------------------|----------|
|              | Ave. Wt.**       | Feed/Wt.*** | Ave. Wt.       | Feed/Wt. | Ave. Wt.         | Feed/Wt. | Ave. Wt.           | Feed/Wt. |
| Experiment 1 | 4.25             | 2.39        | 4.37           | 2.42     | 4.18             | 2.42     | 4.51               | 2.28     |
| Experiment 2 | 4.05             | 2.38        | 4.21           | 2.39     | 4.39             | 2.26     | 4.42               | 2.25     |
| Experiment 3 | 4.23             | 2.47        | 4.22           | 2.44     | 4.18             | 2.32     | 4.42               | 2.36     |
| Experiment 4 | 4.25             | 2.46        | 4.41           | 2.41     | 4.26             | 2.37     | 4.31               | 2.38     |
| Experiment 5 | 4.24             | 2.47        | 4.26           | 2.37     | 4.35             | 2.41     | 4.52               | 2.36     |
| Experiment 6 | 4.25             | 2.40        | 4.39           | 2.46     | 4.24             | 2.37     | 4.49               | 2.37     |
| Average      | 4.21             | 2.43        | 4.31           | 2.42     | 4.27             | 2.34     | 4.45               | 2.33     |
| Change       |                  |             | + .10          | — .01    | + .06            | — .09    | + .24              | — .10    |

\* Incinerated Chicken Ash.

\*\* Average weight in pounds. Each figure is the average of three pens of ten chicks each.

\*\*\* Feed/weight is the expression of the pounds of feed required to produce a pound of chicken.

## EXPERIMENTAL PROCEDURE REPORT NO. 2

Cross breed chicks were purchased from a commercial hatchery for this experiment. They were sexed and added to the battery compartments on the basis of one male to each female. The management was the same as recorded in Report No. 1.

Methionine Hydroxy Analogue (M. H. A.) was used instead of DL Methionine which was used in our earlier experiments. It was added at the rate of two pound per ton of feed or .10 per cent. The fish products consisted of additions of 5 per cent Menhaden Fish Meal and 2-1/2 per cent condensed Menhaden Fish Solubles to the diets. All diets were equated to provide 1.02-1.05 per cent calcium, .66 to .68 per cent phosphorus, 1005 to 1007 calories of productive energy per pound of diet and adjusted to comparable protein levels by adjusting the corn, soybean oil meal and stabilized feed grade fat.

## RESULTS AND DISCUSSIONS REPORT NO. 2

When interpreting the results from this experiment it is apparent that as the protein level increased both growth and feed utilization improved on the unsupplemented diets. Both M. H. A. and fish products improved growth. A combination of the two produced somewhat better growth by the seventh and tenth weeks than either alone. The combination of M. H. A. and fish products appeared to have so balanced amino acids as to cause the chicks to respond practically as well on the 21 as on the 24 per cent protein diet. This indicates that this level could be recommended with comparative safety for commercial use.



The growth response and feed utilization were both inferior in this test to what had been anticipated. It was decided therefore to determine the chick response to a (UGF) supplement on a phosphorus deficient diet compared to a phosphorus adequate diet for the next experiment. This will be presented as Report No. 3.

TABLE II A  
CHICK EXPERIMENTS — 4 WEEKS OF AGE

|              |         |       | Negative<br>Control |              | M. H. A.**  |              | Fish<br>Products |              | + M. H. A.<br>+ Fish Products*** |              |
|--------------|---------|-------|---------------------|--------------|-------------|--------------|------------------|--------------|----------------------------------|--------------|
| Experiment 1 |         |       | Ave.*<br>Wt.        | Feed/<br>Wt. | Ave.<br>Wt. | Feed/<br>Wt. | Ave.<br>Wt.      | Feed/<br>Wt. | Ave.<br>Wt.                      | Feed/<br>Wt. |
| 18 %         | Protein | Diets | .74                 | 1.91         | .78         | 1.78         | .83              | 1.74         | .79                              | 1.83         |
| 21 %         | Protein | Diet  | .83                 | 1.71         | .87         | 1.64         | 1.03             | 1.56         | 1.00                             | 1.55         |
| 24 %         | Protein | Diet  | .95                 | 1.63         | .94         | 1.64         | .92              | 1.60         | 1.02                             | 1.50         |
| Experiment 2 |         |       |                     |              |             |              |                  |              |                                  |              |
| 18 %         | Protein | Diet  | .68                 | 2.33         | .71         | 2.27         | .69              | 2.23         | .72                              | 2.22         |
| 21 %         | Protein | Diet  | .74                 | 2.14         | .76         | 2.09         | .75              | 2.17         | .78                              | 2.13         |
| 24 %         | Protein | Diet  | .79                 | 2.03         | .77         | 2.07         | .78              | 2.08         | .76                              | 2.06         |
| Average      |         |       | .79                 | 1.96         | .81         | 1.92         | .83              | 1.90         | .85                              | 1.89         |
| Change       |         |       |                     |              | + .02       | — .04        | + .04            | — .06        | + .06                            | — .07        |

\* Each weight in pounds is the average of three pens of ten chicks each.

\*\* Methionine Hydroxy Analogue used at the rate of 10 per cent of the diet.

\*\*\* Were used as a single treatment and consisted of a dietary level of 5 per cent menhaden fish meal and 2.5 per cent condensed menhaden fish solubles.

TABLE II B  
CHICK EXPERIMENTS — 7 WEEKS OF AGE

|              |         |       | Negative<br>Control |              | M. H. A.**  |              | Fish<br>Products |              | + M. H. A.<br>+ Fish Products*** |              |
|--------------|---------|-------|---------------------|--------------|-------------|--------------|------------------|--------------|----------------------------------|--------------|
| Experiment 1 |         |       | Ave.*<br>Wt.        | Feed/<br>Wt. | Ave.<br>Wt. | Feed/<br>Wt. | Ave.<br>Wt.      | Feed/<br>Wt. | Ave.<br>Wt.                      | Feed/<br>Wt. |
| 18 %         | Protein | Diets | 1.87                | 2.30         | 2.11        | 2.12         | 2.09             | 2.15         | 2.05                             | 2.11         |
| 21 %         | Protein | Diets | 2.05                | 2.13         | 2.25        | 2.06         | 2.45             | 2.02         | 2.39                             | 2.06         |
| 24 %         | Protein | Diets | 2.36                | 2.02         | 2.36        | 2.03         | 2.34             | 1.92         | 2.49                             | 1.95         |
| Experiment 2 |         |       |                     |              |             |              |                  |              |                                  |              |
| 18 %         | Protein | Diets | 1.86                | 2.61         | 1.94        | 2.50         | 1.89             | 2.61         | 1.99                             | 2.45         |
| 21 %         | Protein | Diets | 1.95                | 2.56         | 2.01        | 2.42         | 2.06             | 2.38         | 2.08                             | 2.36         |
| 24 %         | Protein | Diets | 1.97                | 2.57         | 2.06        | 2.37         | 2.10             | 2.28         | 2.08                             | 2.43         |
| Average      |         |       | 2.01                | 2.37         | 2.12        | 2.25         | 2.16             | 2.23         | 2.18                             | 2.23         |
| Change       |         |       |                     |              | + .11       | — .12        | + .15            | — .14        | + .17                            | — .14        |

\* Each weight in pounds is the average of three pens of ten chicks each.

\*\* Methionine Hydroxy Analogue used at the rate of 10 per cent of the diet.

\*\*\* Were used as a single treatment and consisted of a dietary level of 5 per cent menhaden fish meal and 2.5 per cent condensed menhaden fish solubles.

TABLE II C

CHICK EXPERIMENTS — 10 WEEKS OF AGE

|                   | Negative Control |              | M. H. A.**  |              | Fish Products |              | + M. H. A.<br>† Fish Products*** |              |
|-------------------|------------------|--------------|-------------|--------------|---------------|--------------|----------------------------------|--------------|
|                   | Ave.*<br>Wt.     | Feed/<br>Wt. | Ave.<br>Wt. | Feed/<br>Wt. | Ave.<br>Wt.   | Feed/<br>Wt. | Ave.<br>Wt.                      | Feed/<br>Wt. |
| Experiment 1      |                  |              |             |              |               |              |                                  |              |
| 18 % Protein Diet | 3.44             | 2.75         | 3.62        | 2.66         | 3.64          | 2.65         | 3.67                             | 2.54         |
| 21 % Protein Diet | 3.63             | 2.67         | 3.84        | 2.60         | 3.98          | 2.54         | 4.00                             | 2.54         |
| 24 % Protein Diet | 3.98             | 2.54         | 3.92        | 2.65         | 3.92          | 2.43         | 4.07                             | 2.56         |
| Experiment 2      |                  |              |             |              |               |              |                                  |              |
| 18 % Protein Diet | 3.19             | 3.02         | 3.31        | 2.90         | 3.33          | 2.96         | 3.34                             | 2.90         |
| 21 % Protein Diet | 3.33             | 3.06         | 3.36        | 2.90         | 3.44          | 2.85         | 3.48                             | 2.80         |
| 24 % Protein Diet | 3.33             | 3.04         | 3.42        | 2.81         | 3.50          | 2.73         | 3.47                             | 2.89         |
| Average           | 3.48             | 2.84         | 3.58        | 2.75         | 3.64          | 2.69         | 3.67                             | 2.71         |
| Change            |                  |              | + .10       | — .09        | + .16         | — .15        | + .19                            | — .13        |

\* Each weight in pounds is the average of three pens of ten chicks each.

\*\* Methionine-Hydroxy Analogue used at the rate of 10 per cent of the diet.

\*\*\* Were used as a single treatment and consisted of a dietary level of 5 per cent menhaden fish meal and 2.5 per cent condensed menhaden fish solubles.

### EXPERIMENTAL PROCEDURE REPORT NO. 3

Only one experiment is presented in this report. It was completed in 1960 and additional research in this category is planned. White Rock cockerel chicks were used. They were grown in batteries and managed the same as those described in Report No. 1.

A corn-soy-fat diet was used as the control in the low calcium and phosphorus series to which was added 1 per cent increments of Menhaden Fish Meal from one through seven per cent. The same control diet was used for the diets with higher calcium and phosphorus levels except that one per cent dicalcium phosphate with an analysis of 18 per cent phosphorus and 26 per cent calcium was added. The increments of fish meal were the same as those superimposed upon the low calcium and phosphorus series. All diets were equated for protein and energy. The calcium and phosphorus levels recorded in Tables 3A and 3B were determined by chemical analysis.

### RESULTS AND DISCUSSION — REPORT 3

The objective of this experiment was to determine the level of fish meal supplemented or unsupplemented with dicalcium phosphate required to produce the greatest growth in broilers. A safe interpretation of this data for use in practical feed formulation would appear to be 5 per cent fish meal supplemented with one per cent dicalcium phosphate or a level of approximately .79 total phosphorus. This level is higher than usually specified as adequate but may be due to the part from plant sources that is partially unavailable.



From the standpoint of (UGF) it is interesting to note that the chicks responded differently to the fish meal supplementation on the low phosphorus diets than to those diets approximating phosphorus adequacy. This appears to lend support to the theory of «limiting factors» in that a diet deficient in one nutrient may limit the growth response to another nutrient. In this experiment a phosphorus deficiency appears to have been very effective in limiting the growth response attributable to unidentified growth factors in fish meal. Based on these results and other data from this laboratory it appears desirable to recommend that a corn-soy-experimental diet be supplemented with the equivalent of one per cent dicalcium phosphate, 5 per cent fish meal, 2-1/2 per cent condensed fish solubles and adjusted in the calcium level for an optimum (UGF) response to the fish factor.

TABLE III A

WHITE ROCK COCKEREL CHICKS — 4 WEEKS OF AGE

| Treatment  | % Total |       | Ave. Wt. | Feed/ Wt. | : | % Total |       | Ave. Wt. | Feed/ Wt. |
|------------|---------|-------|----------|-----------|---|---------|-------|----------|-----------|
|            | Ca.     | Phos. |          |           |   | Ca.     | Phos. |          |           |
| Corn-soy   | .55     | .47   | .98      | 1.87      | : | 1.07    | .65   | 1.07     | 1.68      |
| + 1 % Fish | .84     | .50   | .98      | 1.75      | : | 1.14    | .68   | 1.15     | 1.64      |
| + 2 % Fish | .89     | .53   | 1.01     | 1.70      | : | 1.16    | .70   | 1.22     | 1.67      |
| + 3 % Fish | .93     | .56   | 1.04     | 1.68      | : | 1.21    | .73   | 1.16     | 1.61      |
| + 4 % Fish | .98     | .59   | 1.10     | 1.66      | : | 1.26    | .76   | 1.16     | 1.62      |
| + 5 % Fish | 1.02    | .62   | 1.17     | 1.71      | : | 1.32    | .79   | 1.23     | 1.61      |
| + 6 % Fish | 1.10    | .65   | 1.11     | 1.62      | : | 1.37    | .82   | 1.22     | 1.66      |
| + 7 % Fish | 1.13    | .68   | 1.14     | 1.65      | : | 1.43    | .85   | 1.23     | 1.64      |

Menhaden fish meal was used in this experiment. The control diets consisted of corn, dehulled soybean oil meal supplemented with minerals and vitamins.

Each weight is the average of four pens of ten chicks each.

The calcium and phosphorus levels were determined by chemical analysis.

TABLE III B

WHITE ROCK COCKEREL CHICKS — 8 WEEKS OF AGE

| Treatment  | % Total |       | Ave. Wt. | Feed/ Wt. | : | % Total |       | Ave. Wt. | Feed/ Wt. |
|------------|---------|-------|----------|-----------|---|---------|-------|----------|-----------|
|            | Ca.     | Phos. |          |           |   | Ca.     | Phos. |          |           |
| Corn-soy   | .55     | .47   | 2.80     | 2.33      | : | 1.07    | .65   | 3.16     | 2.21      |
| + 1 % Fish | .84     | .50   | 2.84     | 2.30      | : | 1.14    | .68   | 3.43     | 2.12      |
| + 2 % Fish | .89     | .53   | 2.86     | 2.23      | : | 1.16    | .70   | 3.45     | 2.20      |
| + 3 % Fish | .93     | .56   | 3.02     | 2.22      | : | 1.21    | .73   | 3.38     | 2.12      |
| + 4 % Fish | .98     | .59   | 3.16     | 2.22      | : | 1.26    | .76   | 3.41     | 2.17      |
| + 5 % Fish | 1.02    | .62   | 3.37     | 2.18      | : | 1.32    | .79   | 3.50     | 2.13      |
| + 6 % Fish | 1.10    | .65   | 3.25     | 2.17      | : | 1.37    | .82   | 3.43     | 2.19      |
| + 7 % Fish | 1.13    | .68   | 3.42     | 2.11      | : | 1.43    | .85   | 3.53     | 2.13      |

The treatments and conditions were the same as those recorded at the bottom of Table 3A.

## SUMMARY

References have been cited on unidentified growth factor research reported in 1960 and comments have been made on the growth effect and importance of such factors as zinc, stabilized feed grade fat and pellets in practical poultry feeding.

Research conducted at the Delaware Experiment Station has demonstrated the presence of a growth factor in incinerated chick ash. This research is being continued to determine if minerals other than zinc are responsible for the increased growth. The growth response of 1 per cent chick ash and .1 per cent DL Methionine were additive when the chicks were four weeks old but appeared synergistic when they were seven and ten weeks of age.

The protein level of the diet has been shown to interact with growth factor response. The chick growth from a corn-soy-fat diet increased as the protein level increased through 18, 21 and 24 per cent protein. The addition of 5 per cent menhaden fish meal and 2-1/2 per cent menhaden fish solubles appeared to reduce the protein requirement to 21 per cent for optimum growth of the chicks in this experiment. It appears probable that improved amino acid balance was the factor primarily responsible for improved protein utilization.

In a preliminary experiment it was determined that 5 per cent menhaden fish meal and one per cent dicalcium phosphate appeared to meet the chicks requirement for phosphorus. It also appeared that the chicks responded with less growth to the (UGF) in fish meal when fed a phosphorus deficient diet than when it approached adequacy. This appears to support the contention that dietary deficiencies may substantially reduce growth responses to unidentified factors.

The data from this experiment plus other data indicates that 5 per cent menhaden fish meal, 2-1/2 per cent condensed menhaden fish solubles, .80 per cent total phosphorus balanced for calcium is an excellent supplement to a corn-soy-fat experimental diet for the production of optimum (UGF) response to the fish factor.

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# NUTRITIONAL VALUE OF ENZYME SUPPLEMENTS TO FEEDS FOR ANIMALS

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The addition of enzyme supplements to manufactured feeds for various types of animals has been reported from time to time during the past several decades. In many instances the beneficial effects reported have not been confirmed by other investigators and the use of such materials in feed manufacturing never became very extensive. Some of the earlier reports showing the effect of adding fermentation products containing enzyme activity to feeds for chickens appeared in the 20's. Following these reports, a number of years passed before experiments with enzyme supplements were again reported. In general, most of these experiments involved the use of diets high in cellulose and the general objective was to improve the utilization of cellulose by the use of fermentation enzyme preparations.

More recently, a number of reports on the use of enzyme supplements in different types of feeds for different animals have appeared. The basis for use of supplements in these experiments has been somewhat different from that of the earlier work in that enzymes have been added to specified types of diets for a particular type or age of animal. The studies reported from Iowa State on enzyme supplements for young pigs were directed toward improving utilization of feed ingredients not ordinarily consumed by the very young pig. The results showed, for example, that proteins of plant origin and in particular, soybean oil meal protein, were not digested well by the young pig, and that addition of pepsin to a diet containing plant proteins improved their utilization. The Iowa State results suggest that the very young



mammal does not secrete enzymes that hydrolyze proteins other than those found in milk, or that the amount of enzyme secreted is insufficient to digest plant proteins. The results also demonstrated that young pigs suffering with diarrhea were benefited to a much greater extent by the addition of enzyme supplements to their diet than pigs which were in apparent good health.

The results of experiments conducted at Washington State University with chicks and turkeys were again based on the use of enzyme supplements to improve the utilization or nutritional value of a specific ingredient or component of the diet. When we considered the composition of cereal grains such as corn and barley, as indicated by proximate analysis figures, it was evident that the marked difference in feeding value of these two grains for poultry could not be accounted for by a difference in crude fiber content of the two grains, or in the energy content as indicated by the nitrogen free extract (NFE) values. This was even more apparent when the composition of pearled barley (hull and outer layers removed) was compared to that of corn (Table 1). Pearled barley was even lower in crude fiber than corn and higher in NFE, yet when it was fed to chicks as the only cereal grain in the diet, it did not support growth or feed conversion comparable to that obtained with corn. Indeed, the results obtained with such pearled barley were little, if any, better than those obtained with regular ground barley, (Table 2).

TABLE I  
PROXIMATE ANALYSIS OF GRAINS

| Grain | Prot.<br>% | Ext.<br>% | Ether     |  | Ash<br>% | NFE<br>% | Moist<br>% |
|-------|------------|-----------|-----------|--|----------|----------|------------|
|       |            |           | Fib.<br>% |  |          |          |            |
| Corn  | 9.9        | 4.1       | 2.1       |  | 1.4      | 71.6     | 10.9       |
| D B   | 13.7       | 1.0       | 1.0       |  | 2.7      | 72.0     | 9.6        |
| R B   | 13.1       | 2.1       | 6.0       |  | 3.1      | 66.3     | 9.4        |

Productive energy Cal.

|                 |      |
|-----------------|------|
| Corn            | 1145 |
| Dehulled barley | 947  |
| Regular barley  | 811  |

TABLE II  
EFFECT OF SUBSTITUTING BARLEY AND PEARLED BARLEY FOR CORN  
ON CHICK GROWTH AND FEED EFFICIENCY

| Ration         | Av. wt.<br>4 weeks | Feed<br>Efficiency |
|----------------|--------------------|--------------------|
|                | gms.               |                    |
| Corn           | 354                | 1.87               |
| Pearled barley | 292                | 2.20               |
| Regular barley | 275                | 2.26               |

A number of possibilities were investigated to obtain an explanation for the poor feeding value of barley. The experiments conducted showed that addition of various amino acids to chick diets did not improve the nutritional value of this grain. It was also found that different methods of treating or preparing the barley before mixing it in the feed, such as steam rolling, pulverizing, and autoclaving, did not improve its nutritional value. Addition of tallow to a barley containing diet improved both growth and feed conversion.

Because of a peculiar effect of barley on the excreta of birds fed diets with this grain, it was suggested that a considerable part of the barley was not being digested. An enzyme supplement of fermentation origin was then added to a diet containing pearled barley, and the results showed a phenomenal increase in both chick growth and feed utilization (Table 3). Following this

TABLE III

ENZYME AND IMPROVEMENT OF BARLEY

|                | Enz.<br>addition<br>gm./lb. | Av. 4 wk.<br>wt.<br>gms. | Feed<br>gain |
|----------------|-----------------------------|--------------------------|--------------|
| Corn           | —                           | 383                      | 1.96         |
| Pearled barley | —                           | 319                      | 2.30         |
| Pearled barley | 1.0                         | 375                      | 1.97         |

initial experiment, many additional ones have been conducted at Washington State and elsewhere on the improvement of nutritional value of various cereal grains by many different types of enzyme supplements. While our results showing that enzyme supplements would improve the nutritional value of barley were quickly confirmed in a number of laboratories, others were unable to confirm our findings. In an effort to determine the reasons for the apparent discrepancy, experiments were conducted to determine the influence of the variety or type of barley on response to dietary enzyme supplements. We found essentially no influence of variety or type of barley on the responses observed (Table 4). It was suspected that the difference in results might be

TABLE IV

FEEDING VALUE OF DIFFERENT VARIETES OF BARLEY (3 WEEK WEIGHTS)

|           | None | 2 gm. FA/lb. |
|-----------|------|--------------|
| Gem       | 155  | 193          |
| Rufflyn   | 156  | 204          |
| Belsford  | 137  | 211          |
| W. Winter | 153  | 206          |
| Gem       | 141  | 190          |
| Hannchen  | 156  | 204          |
| Hanna     | 157  | 191          |
| Haisa     | 163  | 196          |
| Betzes    | 155  | 212          |



accounted for by the source of barley used, or the geographical area in which the grain was grown. Samples were then obtained from many different parts of the United States, and one from Canada. When these different barleys were included at the grain component in a chick diet and fed with and without dietary enzyme supplements, a pronounced difference in response was found. Grains grown in the arid sections of the Western United States responded whereas little or no response was obtained with barleys grown in other parts of the country (Table 5). It was speculated that differences existed in samples

TABLE V  
EFFECT OF DIFFERENT BARLEYS (2 WK.)

| State        | None | F. Enz. | H <sub>2</sub> O Treat. |
|--------------|------|---------|-------------------------|
| Wash         | 82   | 116**   | 124**                   |
| Oregon       | 84   | 124**   | 134**                   |
| N. D. (thin) | 104  | 128**   | 143**                   |
| Wisc. (A)    | 99   | 117*    | 136**                   |
| Wisc. (B)    | 101  | 114     | 137**                   |
| N. Y.        | 110  | 122     | 140**                   |
| Canada       | 106  | 114     | 134**                   |
| N. D. (h)    | 109  | 115     | 132**                   |
| Ark.         | 106  | 117     | 140**                   |
| Minn. (A)    | 112  | 119     | 137**                   |
| Minn. (B)    | 117  | 118     | 137*                    |

of barley grown in the Western part of the United States and in the other parts of the country that normally have a much heavier rainfall, particularly during the late growing and harvest season because of the repeated wetting and drying processes. It was observed that the decreased response to enzyme supplements to barley grown in the midwest and Eastern United States was associated with considerably better chick growth on the basal diet, and that the average weights of chicks fed all of the different samples in combination with enzyme supplements were more nearly the same.

At this point in my discussion, I would like to describe results of experiments on barley in which methods of improvement other than addition of enzyme supplements to the diet were used. At about the same time that we discovered that enzyme supplements would improve the nutritional or feeding value of barley, we also found that simple wetting and drying of ground barley was even more effective in improving its nutritional value. In this process the ground barley was simply mixed with an equal weight of water, spread in thin layers on metal trays and placed in a electric oven maintained at about 70° C. to dry. The time required for drying was about 15 hours (Table 6). At first it was thought that this temperature was sufficiently high to prevent significant microbial growth, but it was soon discovered that many organisms were capable of growth at the temperature reached by the drying grain. It was found later that microbial fermentation probably brings about most, if not all, of the improvement in nutritional value of barley by this process, which has often been referred to as water-treatment. Studies in

TABLE VI

EFFECT OF ENZYME SUPPLEMENTATION & WATER TREATMENT OF  
BARLEY ON PERFORMANCE OF CHICKS

| Treatment                  | Av. wt.<br>3 wks. | Feed<br>gain |
|----------------------------|-------------------|--------------|
|                            | gms.              |              |
| None                       | 153               | 2.16         |
| Fungal amylase (2 gm./lb.) | 201               | 1.95         |
| Water treated barley       | 226               | 1.83         |

which the barley was sterilized and autoclaved prior to drying at 100° C. showed little or no improvement (Table 7). Similarly, barley that was wet and dried at 95° without sterilizing was not improved nearly as much as when the lower drying temperature of 70° was used. It was also found that inoculation of sterilized barley with a contaminating *Bacillus* type of organism, isolated from our feed preparation laboratory, gave an improvement essentially comparable to that obtained with unsterilized water-treated barley. In a follow-up study, inoculation with *Bacillus subtilis* (ATCC-9943) brought about a marked improvement in the nutritional value of sterilized barley dried at 70°, (Table 8).

TABLE VII

EFFECT OF WET AUTOCLAVED BARLEY ON PERFORMANCE OF CHICKS

| Grain  | Treatment      | Enzyme | Av. wt.<br>3 wk. | Feed<br>gain |
|--------|----------------|--------|------------------|--------------|
|        |                |        | gm.              |              |
| Corn   | —              | —      | 227              | 1.85         |
| Barley | —              | —      | 196              | 2.10         |
| Barley | Water treated  | —      | 228              | 1.90         |
| Barley | Water treated  | +      | 239              | 1.99         |
| Barley | Wet autoclaved | —      | 195              | 2.24         |
| Barley | Wet autoclaved | +      | 251              | 1.92         |

TABLE VIII

STERILIZING AND WATER IMPROVEMENT OF BARLEY

| Treatment               | Dry Temp.<br>0 C. | Chick wt.<br>2 wk. |
|-------------------------|-------------------|--------------------|
| None                    | —                 | 84                 |
| Sterilized              | 70                | 93                 |
| Sterilized & inoculated | 70                | 112                |
| Sterilized & inoculated | 95                | 84                 |



The question of the role of enzymes *endogenous to barley in water improvement* still remains unanswered. It is fairly clear, however, that such enzymes are not essential to improvement of barley by water treatment.

With this information on water treatment of barley in mind, I would now like to return to our studies on barley grown in different geographical areas. It was considered possible that in the course of wetting and drying of barley in areas of high rainfall microorganisms might make considerable surface growth and in so doing produce enzymes of the type involved in water treatment of barley in sufficient quantities to improve the value of such grain when fed to chicks. To test this hypothesis, barley grown in the midwest which was not improved by addition of dietary enzymes was subjected to an autoclaving treatment which would presumably inactivate enzymes. This barley was then fed to chicks with and without dietary enzyme supplements. The results showed a marked reduction in the feeding value of such autoclaved barley and that a significant response to enzymes was then obtained. It is interesting that the nutritional value of such autoclaved barley was quite comparable to that of barley grown in the arid western regions. It would, therefore, appear that the difference in nutritional value of barley grown in different regions could be attributed to the presence of a «heat labile» substance, perhaps enzymes, resulting from surface growth of microorganisms.

Let us now consider work conducted to study the enzymes or factors responsible for improvement in the nutritional value of barley. It was first suspected that the improvement observed might be associated with alpha amylase activity of such supplements, since in many instances the products were produced and standardized for alpha amylase activity. It soon became apparent, however, that the explanation was not this simple. When a crystalline alpha amylase was fed as a supplement to a chick diet containing barley, no growth response was observed (Tables 9 & 10). A highly purified

TABLE IX  
EFFECT OF CRYSTALLINE ALPHA AMYLASE ON CHICK GROWTH

|                              | Average weight, 4 weeks |
|------------------------------|-------------------------|
| Corn                         | 420                     |
| Barley                       | 328                     |
| Barley + crystalline amylase | 333                     |
| Barley + Clarase 300         | 356                     |

TABLE X  
INEFFECTIVENESS OF CRYSTALLINE ALPHA AMYLASE

| Supplement                                     | Average weight, 2 weeks | Feed Gain |
|------------------------------------------------|-------------------------|-----------|
|                                                | grams                   |           |
| None                                           | 151                     | 1.66      |
| Bacterial enzyme prep.                         | 172                     | 1.55      |
| Crystalline Bacterial amylase<br>(10 mg./lb.)  | 147                     | 1.80      |
| Crystalline Bacterial amylase<br>(100 mg./lb.) | 146                     | 1.67      |

alpha amylase of a different origin was also inactive. In the course of testing a large number of enzyme supplements produced and standardized for amylase activity, proteinase activity, lipase activity, hemicellulase activity, etc., all of these supplements were found to be about equally effective in promoting chick growth or improving the nutritional value of barley. Along with these observations, it was found that enzyme supplements not produced by bacterial or mold fermentations were essentially inactive for the chick, even though they contained high amounts of enzyme activity as measured by starch-splitting, protein digestion, etc. It therefore appears that growth promoting activity of enzyme supplements for chicks can not yet be correlated with any of the enzyme standardizations commonly used in other applications.

In the course of our studies we have found that a crystalline bacterial proteinase derived from *B. subtilus* fermentation, possessed chick growth promoting activity (Table 11). The response obtained to this preparation was only about half as great as that obtained with unpurified fermentation products.

TABLE XI  
EFFECT OF PROTEOLYTIC ENZYME AND ENZYME PREPARATION ON  
POULTS (6-13 DAYS)

| Supplement    | Mg./lb.      | Av. wt.<br>gain | F. E. |
|---------------|--------------|-----------------|-------|
| —             | —            | 57              | 1.83  |
| Nagarse crys. | 2, 4, 8      | 71              | 1.59  |
| Biopraxe con. | 20, 40, 80   | 75              | 1.53  |
| Biopraxe PN10 | 60, 120, 240 | 76              | 1.49  |
| F. A.         | 2 gr.        | 84              | 1.45  |
| MK 124        | 114          | 80              | 1.48  |

It would be wise to consider the possibility that the chick growth promoting factor in fermentation products produced as enzyme supplements is due to something other than enzymes *per se*. Final proof concerning the active factor must await chemical isolation and identification. In the meantime, results of studies on the effect of such supplements on metabolizable energy derived from barley by chicks, show a significant increase in this respect (Table 12). The fact that such a supplement enables the chick to obtain a greater amount of energy from barley, would lend support to the enzyme hypothesis, unless we assume that other factors may possibly interfere with metabolism of components of barley, and that the supplements merely detoxify such substances.

In the course of our investigations, we have studied the effect of enzymes on nutritional value or utilization of other cereal grains and have found that wheat, oats, and rye are also significantly improved by enzyme supplements (Table 13). A more extensive study was conducted with wheat and there



TABLE XII

METABOLIZABLE ENERGY DETERMINATIONS OF TREATED AND UNTREATED  
PEARLED BARLEY (DRY WEIGHT BASIS)

|                            | Metabolizable<br>energy |
|----------------------------|-------------------------|
|                            | Cal./lb.                |
| None                       | 1370                    |
| Fungal amylase (2 gm./lb.) | 1696                    |
| Water treated              | 1728                    |

TABLE XIII

EFFECT OF ENZYMES WITH DIFFERENT CEREAL GRAINS (CHICKS)

| Grain  | Enzyme | Av. wt.<br>8 wks. | Feed<br>gain |
|--------|--------|-------------------|--------------|
|        |        | gm.               |              |
| Corn   | No     | 1075              | 2.45         |
|        | Yes    | 1078              | 2.44         |
| Barley | No     | 995               | 2.66         |
|        | Yes    | 1074              | 2.60         |
| Oats   | No     | 886               | 2.83         |
|        | Yes    | 1021              | 2.75         |

was a strong indication that the variety or type of wheat used, significantly influenced the response to enzyme supplements.

Corn and milo have not been improved by the use of enzyme supplements except possibly to a very slight degree. In contrast, these two grains have been significantly improved a number of times by the water-treating process, (Table 14).

TABLE XIV

EFFECT OF WATER TREATMENT OF GRAIN ON CHICK GROWTH AND  
FEED EFFICIENCY

| Grain  | Water<br>treated | Av. wt.<br>4 wks. | Feed<br>gain |
|--------|------------------|-------------------|--------------|
| Corn   | —                | 409               | 1.92         |
| Corn   | +                | 414               | 1.80         |
| Barley | —                | 346               | 2.15         |
| Barley | +                | 385               | 2.00         |
| Oats   | —                | 302               | 2.28         |
| Oats   | +                | 376               | 2.10         |

## ENZYMES FOR LAYING HENS

Following the early studies with chicks, a preliminary experiment was conducted with laying hens to determine the influence of both enzyme supplements and water-treatment on the utilization of barley by older birds. Essentially no improvement was observed in this study. Since that time a much more extensive study has been conducted by Berg on laying hens, and the results again showed that the use of enzyme supplements in feeds for pullets 8 weeks or older, was of little or no value (Table 15). It was noted, however, that the litter in pens of hens fed barley plus an enzyme supplement, was somewhat lower in moisture content than that of comparable control groups. Results from Wyoming and Utah indicated a response to enzyme supplements for laying hens, but since that time additional studies at Utah have shown no response with laying hens. It would, therefore, appear that older birds develop a tolerance to a factor contained in barley that depresses growth of young chicks, or that an adaptation occurs, either in the type or amount of enzymes secreted, so that barley can be utilized without the need for supplementary enzymes of the type that are effective in chick nutrition.

TABLE XV  
ENZYMES FOR LAYING HENS

| Treatment            | % lay | Lb. feed<br>doz. eggs | Wt.<br>gain |
|----------------------|-------|-----------------------|-------------|
|                      |       |                       | lb.         |
| Corn                 | 74.6  | 4.00                  | 0.25        |
| Barley               | 73.4  | 4.48                  | 0.02        |
| Water treated barley | 72.8  | 4.39                  | 0.10        |
| Barley + enzyme      | 75.7  | 4.38                  | 0.10        |

## ENZYMES FOR TURKEYS

The results of experiments with turkeys fed barley and enzymes are essentially comparable to those obtained in chick studies. There is a suggestion, however, that the magnitude of response to enzyme supplements in turkeys is greater than that observed in chicks (Table 16).

TABLE XVI  
EFFECT OF ENZYMES AND WATER TREATMENT ON PERFORMANCE OF  
TURKEYS (8-24 WEEKS)

| Grain                | Enzyme<br>level | Av. wt.<br>24 wks. | Feed<br>gain |
|----------------------|-----------------|--------------------|--------------|
| Barley               | 0               | 8159               | 4.59         |
| Barley               | 1/4             | 7948               | 4.61         |
| Barley               | 1/3             | 8133               | 4.48         |
| Barley               | 2               | 8509               | 4.36         |
| Barley               | 5               | 8466               | 4.50         |
| Water treated barley | —               | 8509               | 4.64         |
| Corn                 | —               | 8175               | 4.40         |



## ENZYMES FOR GOSLINGS

One experiment was conducted with goslings to demonstrate the response to enzyme supplements added to a feed containing barley. At the end of seven weeks, those fed the control diet with the enzyme supplement averaged 4.26 pounds and those fed the same diet with 2 grams of fungal enzyme added per pound of feed averaged 5.50 pounds. The feed conversion for these two treatments was 3.74 and 3.23, respectively.

## ENZYMES FOR RABBITS

Results have been reported from the Dawes Laboratories showing that addition of enzyme supplements to diets for young rabbits significantly increased growth and feed conversion.

## ENZYMES FOR SWINE

A considerable amount of work has been conducted to determine the influence of adding enzymes to swine rations containing barley. Only a limited number of reports have appeared in the literature. The results obtained at Oregon State College showed little or no response to enzyme supplements. This type of finding was also made in a preliminary experiment conducted at Washington State. It would appear that as swine grow older, they are capable of utilizing barley in much the same manner as older chickens do, and that supplementary enzymes are not required for this purpose.

## ENZYMES FOR CATTLE AND SHEEP

Since the initial report from Iowa State showing that addition of an enzyme supplement to cattle rations containing low-moisture corn greatly increased daily gain and feed efficiency and that the utilization of high-moisture corn was not improved by such a supplement, a great many experiments have been conducted, both in university laboratories and in private feed lot operations (Table 17). The results of these experiments are characterized by the great variability obtained in response to enzymes from one experiment to

TABLE XVII

ENZYME SUPPLEMENTS AND CATTLE GAINS (IOWA)

|        | Daily gain | Feed/100<br>lbs. gain |
|--------|------------|-----------------------|
| None   | 1.86       | 1201                  |
| Enzyme | 1.98       | 1129                  |

another, or from one laboratory to another. For the most part, the results of such studies have not yet appeared in scientific journals. It would appear that highly significant responses have been obtained in enough experiments to warrant continuing investigations to determine the basis of the extreme variability encountered. In two experiments conducted at Washington State, no response was obtained in the first, and in the second, highly significant effects were shown. In an experiment at Montana State College, the addition of an enzyme supplement to cattle fattening rations consisting primarily of barley gave approximately a 7 % increase in gain.

It would appear that the situation in experiments with cattle and sheep might be comparable or similar to that which existed in experiments with chicks prior to the result showing the tremendous influence of the origin of barley on response to enzymes.

### SUMMARY

The basis for use of enzyme supplements of various kinds in manufactured feeds has progressed considerably since the time when they were simply added to feeds in the hope of improving cellulose utilization. Based on present information, enzymes are of value when used as supplements to young pig diets which contain plant proteins instead of milk proteins. The value of such supplements in feeding poultry appears to be related specifically to the type of ingredient contained in the diet and not simply to cellulose content. Results show that feeds containing cereal grains such as barley, oats, rye and wheat are improved by certain types of enzyme preparations, and that little or no value is derived from their use in diets containing corn.

Supplements which have been found to be active in promoting growth or feed utilization in chicks have also been shown to be effective in improving the growth of lambs and daily gains and feed conversion in cattle under some conditions. Variability in the response to enzyme supplements added to cattle rations has been much greater than that observed in studies with chicks and turkeys.

The results of studies to date do not show the nature of the active principles contained in supplements that are effective in promoting growth or increased feed utilization. Based on the fact that metabolizable energy derived from barley is increased by such supplements, it is highly suggestive that some type of enzyme is responsible for the effect.



## MINERAL METABOLISM — RECENT STUDIES AND OUT- STANDING PROBLEMS

BY

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In the Proceedings of the 1st International Animal Feed Symposium in 1959 Davis presented a comprehensive review of mineral element requirements of livestock. In the same year Underwood (1) reviewed fundamental and practical aspects of mineral element metabolism covering results published up to June 1958. With this in mind the present report will mainly deal with work reported since these earlier reviews were prepared.

### CALCIUM AND PHOSPHORUS

The application of X-ray examination and bone ash determinations in field studies of Ca and P metabolism has recently been described. These studies, using sheep, have been designed to investigate the depletion of skeletal reserves during lactation and the extent of skeletal replenishment during the next pregnancy (2, 3). On daily Ca intakes of 2 g., up to 18 % of the bone mineral was lost by mid lactation while on rations providing 1.2 g. P daily the loss of skeletal ash at this time was 40 %. Losses were not made good 60 days after the end of lactation when animals were maintained on these intakes of Ca and P. A Ca intake of 5 g./day, and, in a further group of animals, a P intake of 4.5 g. day reduced the extent of skeletal resorption at mid lactation to 6.5 % and 19 % respectively. On both these diets skeletal repair was virtually complete 2 months after the end of lactation.

In growing wethers on a diet low in Ca and P and metabolizable energy, the provision of a high energy supplement, while increasing rate of growth resulted in a marked decrease in bone density and percentage ash content. In these studies it was found that restriction of Ca and P supplies could be detected by X-ray examination of the cervical vertebrae of the intact animal when resorption of the skeleton corresponding to a loss of 20 % of bone ash had occurred.

Studies on the Ca and P balance of the sow during pregnancy and lactation have been carried out by Lenkeit et al. (4). During pregnancy the retention of these elements from rations providing between 7.5 and 29.6 g. Ca and 6.2 and 23.5 g. P daily, exceeded losses at parturition by 69-504 g. for Ca and 73-423 g. for P. Immediately after parturition these stores are lost not only as a result of the onset of lactation but also through a temporary phase of increased faecal output of Ca and P. The magnitude of this excretory phase is related to the extent of storage of these elements before parturition.

The value of bone ash determinations as a diagnostic aid in suspected rickets and osteomalacia in the pig has recently been examined by Pullar (5). Preliminary results indicate that ash analysis of the metacarpi and metatarsi may reflect the extent of skeletal demineralization resulting from a dietary insufficiency even before clinical signs or pathological changes occur. A further technique which would appear to be of value in the detection of changes in the degree of mineralization of the skeleton under range conditions is that described by Smith (6) for calves in which caudal vertebrae may be removed from the living animal for ash analysis.

The utilization of different compounds of Ca and P and the influence of dietary carbohydrates and amino acids on the uptake of these elements continues to receive attention. Thus Tillman and Brethour (7) found that both the Ca and the P of Ca phytate were readily utilized by the sheep owing, presumably, to the activity of bacterial phytases in the rumen. It is of interest that while these workers found the true digestibility of P from this source to be about 90 %, Lofgreen (8) using an isotope dilution technique, found a true digestibility for phytin P of only 33 % the reason for this discrepancy is not apparent. In this last study the true digestibilities of P from dicalcium phosphate, bone meal and soft phosphate were found to be 50, 46 and 14 per cent respectively.

Following up work in which corn oil had been found to have a deleterious effect upon the digestibility of ruminant rations containing corn cobs or cottonseed hulls, and the later work in which Grainger et al. (9) found that the factor in alfalfa ash capable in preventing this effect was calcium, Tillman and Brethour (10) using sheep have examined the effect of corn oil on the digestibility of Ca and P. Addition of 7.5 % oil to the basal ration (cottonseed hulls, alfalfa meal, soybean meal and ground corn) reduced the digestibility of Ca from 63 % to 55 %. Faecal endogenous Ca excretion was not affected, suggesting that the site of interference is within the digestive tract—it is postulated that the formation of soaps with Ca and other cations may be responsible for the detrimental effect of fats in some ruminant rations.

The effects of including calcium lactate at the 1 or 2 % level in the rations of laying hens have recently been investigated (13). Significant increases both in egg production and in egg weight/unit weight of food consumed are



claimed. Doubt is expressed as to whether these results are related specifically to changes in Ca availability in the ration as birds had free access to calcareous grit during experiments.

The effect of lactose in promoting calcium retention in the rat (11, 12) is now well established. Uptake of radiocalcium from the digestive tract of the rat has also been found to be increased, in ascending order of effectiveness, by cellobiose, sorbose, ribose, xylose, lactose, raffinose, melibiose, D-glucosamine, mannitol and sorbose (14).

It has been suggested that these substances enhance Ca uptake from the ileum. The amino acids lysine and arginine have been found to have a similar effect (15).

## MAGNESIUM

Hypomagnesaemic tetany in the dairy cow and the lactating ewe is known in most European countries, in Australasia and in the U. S. A. to cause economic losses, the magnitudes of which are on the increase. Surveys in 1955 indicated that 0.5 % of British and 1 to 2 % of Dutch dairy cattle may become affected in a typical year. A statistical investigation by Kemp (16) showed a significant relationship between nitrogen fertilization of pasture and severity of outbreaks, the suggestion being made that nitrogen favours the development of grasses at the expense of clover and so depresses the overall Mg intake of the grazing animal. Others believe that potassium uptake by the plant may be an important factor in the aetiology of this condition, as for

example in the suggestion of Dutch workers that the ratio  $\frac{\text{Ca} + \text{Mg}}{\text{K}}$  exceeds 2.2 in most tetany-inducing pastures. It is possible however, to cite the occurrence of very many severe outbreaks that can neither be related to low Mg or to high K values in pasture and several recent studies have been devoted to other possible aspects of this problem.

The apparent association of this condition with «lush» growth of pasture has led to the postulate that a high nitrogen intake and, consequently, a high ammonia production in the rumen, may adversely affect Mg absorption (17, 18) and lead to a fall in serum Mg—a result which has been obtained with varying degrees of success experimentally. Even if Mg absorption is blocked by such a process, it has been argued by Blaxter et al. (19), this mechanism would not explain the apparent inability of the adult lactating cow to mobilize skeletal Mg reserves and thus prevent the precipitous fall of plasma Mg so frequently observed unless skeletal exchange reactions are much less active in the adult than they have been found to be in the calf (6). Evidence for the comparative unavailability of bone Mg in the adult is as yet, circumstantial and is based on work such as that of Taylor (20) who found that lactic acid extracted considerably less Mg from ox bone than from calf bone.

A suggested association between low blood Mg levels in «wheat pasture poisoning» in cattle and sheep and high intakes of protein and potassium has been investigated by Fontenot et al. (21) using lambs. Using diets supplemented with soyabean protein and potassium bicarbonate to reproduce the composition of young wheat, faecal excretion of Mg was found to be between 66 and 78 % of intake as compared with 45 to 59 % of intake on

the basal diet of alfalfa hay, corn and cerelose. Increased faecal output of Mg was associated with a decreased plasma level suggesting that absorption or retention of Mg had been influenced by these treatments.

It is possible that these effects of diet on Mg metabolism may, in part, be explained by changes in the pH of the contents of abomasum and duodenum as the results of Storry (22) suggest. Thus, a negative correlation exists between pH and the amount of ultrafilterable Ca and Mg in the abomasum and duodenum, the Ca and Mg becoming bound to suspended particles of food and bacterial debris as the pH rises. It is pointed out that the decreased abomasal acidity associated with the sudden introduction of animals to a diet of «lush» grass or to the feeding of ammonium salts and carbonates or bicarbonates is sufficient to markedly affect the concentration of free ionic Ca and Mg in the abomasum and duodenum — a situation which may, in turn, result in a lowered Mg uptake from the gut.

The question of whether stress factors such as sudden exposure to a cooler environment may play a part in the development of this condition has never been satisfactorily evaluated but, in this connection, it is of interest that Hegsted et al. (23) demonstrated that the Mg requirement of the rat was doubled if animals were reared at 55°F as compared with 78°F.

Remarkable differences have been noted between individual animals maintained on the same diet and in the same environment in the metabolism of dietary Mg. Of two sheep fed herbage during Mg balance trials (24) one animal utilized 13 % of the dietary Mg with an endogenous faecal loss of 100 mg/day and the second, 26 % of dietary Mg with an endogenous faecal loss of 250 mg/day. Similar marked individual differences have been noted in calves with regard to relationships between bone and plasma Mg levels (6).

From the foregoing it appears possible that the appearance of hypomagnesaemia or hypomagnesaemic tetany in cattle and sheep may be influenced by any combination of the following factors; (i) cultural practices influencing herbage composition, (ii) dietary effects on the pH of digestive tract contents influencing binding of Mg and Ca, (iii) the influence of age of animal on exchange reactions between bone and plasma Mg, (iv) stress factors and (v) individual variability in Mg requirement and Mg metabolism. It is perhaps regrettable that of all these factors we know least about changes in plant composition associated with «lush» growth for it is by no means improbable that in, for example, the high non-protein nitrogen fraction of such herbage resides a further clue in the form of compound exerting a pharmacological effect upon Mg transport in the body.

Mayo et al. (25) have recently determined the nature of Mg deficiency symptoms and established the Mg requirement of the young pig. Using semi-purified basal diets (Ca: P ratio 1: 3.4) it was found that cases of tetany appeared and deaths occurred when the diet contained less than 400 p. p. m. Mg. To prevent any appearance of Mg deficiency symptoms 505 p. p. m. Mg had to be provided even though growth rate was not improved by increases in dietary Mg level above 241 p. p. m. Mg in 9 week old pigs or above 334 p. p. m. in pigs three weeks of age. The findings support earlier beliefs that most practical rations can be relied upon to meet Mg requirements for growth.



## ZINC

The years 1955 to 1958 cover a period in which the finding of Tucker and Salmon (26), that parakeratosis in the pig can be cured and prevented by supplementary zinc, was confirmed by many workers. It is now generally accepted that the condition can arise in pigs fed rations containing as much as 40 p. p. m. Zn, and that there is a positive correlation between the Ca content of the diet—at least where the Ca content exceeds requirement—and the severity of the condition. O'Dell and associates (27) have found the zinc requirement of the chick (approx. 35 p. p. m. in diet) to be similarly related to Ca level of the diet. Zn deficiency in the chick is manifested by poor growth and feathering, retarded skeletal calcification, oesophageal parakeratosis and skin lesions.

Studies of Zn metabolism in pigs by Newland et al. (28) using diets containing 0.6 % to 1.2 % Ca indicated that increasing the Ca intake, increases endogenous faecal Zn output. The specific activity of liver Zn (65), following intravenous injection of the isotope, was also increased by such treatment suggesting a higher rate of Zn turnover in animals on high Ca rations.

The influence of dietary additives in apparently modifying Zn utilization from the food has been studied by Kratzer et al. (29) who found that ethylene diamine-tetra-acetic acid (EDTA) increased growth and prevented perosis in turkey poults on a diet which, although containing 25.5 p. p. m. Zn, was markedly improved by addition of supplementary Zn. Similarly, it has been claimed that the additions of citric or acetic acid to the diet of the pig are as effective as added Zn in preventing parakeratosis. Earlier suggestions, based on studies with the pig, that modifications to the protein component of the diet may influence Zn utilization are supported now by the finding that the autoclaving of soya protein improves the growth of turkey poults on diets which, when the untreated protein was included, were incapable of supporting good growth unless Zn was added (29). Similar effects of protein are indicated by the finding of Zeigler et al. that on diets containing 1.23 % Ca the total Zn requirement of the chick is 19 p. p. m. on a casein diet, but between 24 and 39 p. p. m. on a purified soyabean protein diet. The poor availability of Zn in sesame meal has recently been demonstrated (76) when this meal was used in chick rations containing 52 p. p. m. Zn. Increasing the Zn content of the diet by 30 p. p. m. did not result in good growth, levels had to be increased by 60-120 p. p. m. before growth was significantly improved and leg deformities were reduced. Autoclaving the sesame meal improved growth but did not prevent leg deformities; additions of EDTA to the diet greatly improved performance. It is suggested that the variety of sesame seed used (K10) not only contains nonavailable Zn, but also a factor capable of binding supplementary Zn.

The effect of including high levels of soyabean oil or Zn on the development of, or recovery from, parakeratosis in the pig was studied by Hanson et al. (30). It is suggested that an essential fatty acid deficiency may be involved in cases that give only a moderate response to Zn supplements, but at the high levels of oil used in these studies (up to 23 % of the diet) it is difficult to rule out possible effects on Ca utilization (and hence Zn utilization) from the diet.

Studies based on practical rations of the corn, soyabean oil meal type for chicks and poults suggest that such rations may be «borderline» with respect to Zn insofar as growth rate of birds may be improved by additions of 10-50 p. p. m. Zn (31, 32). Diets containing less than 15 p. p. m. Zn fed to laying hens have been found to cause severe malformations in the developing chick embryo (33).

The successful use of zinc sulphate (2 g/week orally or 1 g/week by injection) to control field outbreaks of Zn deficiency in cattle in British Guiana has recently been reported by Legg et al. (34). The condition, which was characterised by poor liveweight gain and skin lesions over up to 40 % of the body area, is believed to be associated with a low Zn content of the grass *Trachypogon polymorphus* (18-22 p. p. m. Zn/g D. M.) — Pangola grass in the area contained rather more Zn (34-42 p. p. m.).

In view of the rapidly expanding practice of adding Zn to livestock rations attention has also been paid to determination of toxic levels of this element in diets. Brink et al. (35) found that in weanling pigs on a corn-soyabean oil meal diet, 1000 p. p. m. was the maximum level tolerated. Toxicity symptoms were depressed rate of gain and feed intake, arthritis, gastritis and enteritis with haemorrhages in the brain, lymph nodes and spleen. Ca added at the 1 % level had no influence on zinc tolerance. Levels of 1200-1400 p. p. m. are not toxic to broilers or laying hens (36). High levels of Zn have been shown to interfere with copper utilization.

## SELENIUM

Since the independent discoveries of the groups working under Schwarz and Scott (37, 38) and Stokstad (39) that Se is active in protecting rats against dietary liver necrosis and chicks against exudative diathesis when diets high in Torula yeast are fed, interest in the nutritional role of this element has greatly increased and the metabolic interactions of Se, vitamin E and various protein sources and, in particular, sulphur amino acids, are being closely investigated. Thus the partial protection against the development of liver necrosis in the rat fed Torula yeast diets obtained by increasing the dietary cystine level, has been shown to be related to both Se contamination and a direct sparing effect of high levels of this amino acid upon vitamin E requirement (40, 41). Similarly, variations in the necrogenic potency of a range of milk powders has been shown to be related to differences in their Se contents presumably arising from differences in production techniques (42).

Within the last 2 years, studies have indicated that Se administration may be beneficial where animals are maintained on diets of a more «practical» nature than the semi-synthetic diets fed in earlier experiments. In 1958 Muth and his associates (43) demonstrated that the inclusion of 0.1 p. p. m. Se in a diet of Ladino clover and alfalfa hay, taken from an area where muscular dystrophy in lambs was common, afforded almost complete protection against the disease. Simultaneously, workers at Cornell (44) found the same protective effect of additions of 1 p. p. m. Se to dystrophogenic diets containing trefoil and grass hay and raw cull kidney beans. In this work, a degree of protection afforded by linseed oil meal appears to be associated with a relatively high Se content of this supplement (1.2 p. p. m.). In New Zealand, oral administration



of 5 mg Se to pregnant ewes gave a rather better protection against congenital muscular dystrophy in lambs than 300 mg- $\alpha$ -tocopherol acetate given orally. A similar superiority of Se over  $\alpha$ -tocopherol was demonstrated in a later trial with lambs, and no differences in degree of control were observed when oral and parenteral administration were compared (45). Sharman et al. (46) have found that oral Se (0.25 mg/day) will give at least as good a control of enzootic muscular dystrophy of suckling beef calves in Scotland as vitamin E (200 mg/week). These workers suggest that the geographical distribution of this disorder may be related to both a deficiency of soil Se and to variations in dietary vitamin E supply arising from the feeding of different rations to the dam.

It has recently been shown that small quantities of Se may improve the growth rate of livestock even where clinical cases of muscular dystrophy have not been observed. McLean et al. (47) in extensive field trials in New Zealand obtained increases in growth ranging from 12 to 40 % when unthrifty lambs were given Se (0.5 or 1 mg orally, or by subcutaneous injection, every 10 days). In trials with 5 month old lambs it was found that the oral administration of 5 mg Se on three occasions was sufficient to reduce the mortality rate of unthrifty lambs from 27 % when untreated to 8 % when treated. Se administration resulted in 2 to 7 lb. greater increases in liveweight gain during a 3 month period (48). Treatment of unthrifty calves with Se in the same area of New Zealand resulted in a 52 % greater liveweight gain over a 4 week period! (49).

With these encouraging results appearing so frequently, further information is now required regarding levels of Se toxic to the ruminant and possible influences of changes in diet on toxicity level. Schwarz has suggested that the minimum chronic toxic dose of selenite Se is approximately 3 to 4 p. p. m. in the diet but has pointed out that the toxicity of Se compounds varies greatly with their chemical constitution and is dependent on the nutritional status of the animal. In Eire (50), levels of 5 p. p. m. in herbage are considered potentially toxic to ruminants. A level of 10 p. p. m. Se in pig diets has been shown to induce toxicity symptoms, lower conception rates and decrease weaning percentages and weight gains of offspring (51).

## COPPER

It is now well known that Cu deficiency diseases in ruminants may be divided into «simple» deficiencies (i. e. a Cu deficiency in the plant resulting in a deficiency in the grazing animal, plant Cu levels below 4 or 5 p. p. m. being associated with such conditions) and «conditioned» deficiencies where some component of the diet restricts the utilization of ingested Cu. «Simple» deficiencies now present few problems either of diagnosis or prevention but, since so little is known of factors which promote or restrict Cu utilization from the diet, the same cannot be said of field cases of «conditioned» Cu deficiency.

The effects of high intakes of molybdenum and sulphate in restricting tissue Cu storage have been clearly established by several workers (52, 53). The mechanism underlying this effect is obscure but recent evidence suggests

that such diets influence Cu distribution within the digestive tract (54) and affect Cu transport and utilization after absorption into the body. A high content of sulphate in the diet of the ewe has been found to result in depletion of tissue Cu stores to the extent that histological indications of damage to nervous tissue occur in the new born lamb (as in field cases of enzootic ataxia or swayback) and the addition of Mo to such diets results in a greater depletion of tissue Cu, more extensive degeneration of nervous tissue, ataxia and, ultimately, death of the offspring (55).

By no means all field cases of Cu deficiency can be attributed to high dietary levels of Mo or sulphate and, as a result, the search for factors influencing Cu utilization from the diet continues. Of importance in this regard may be the findings that animals at grass frequently store less Cu than animals fed hays of similar Cu content (56); the finding that supplements of molasses have a marked effect in preventing Cu storage in the liver (57) and, lastly, the suggestion that Cu retention may be limited by increases in Ca intake (58, 59).

Attempts to control Cu deficiency in the field by dressing pastures with Cu salts have met with varying degrees of success. Control by the subcutaneous injection of Cu complexes has been further developed by Allcroft et al. using Cu glycinate injected into calves and adult cattle (60) (to provide 120 mg Cu/dose) and into sheep (61) (to provide 45 mg Cu/dose). The use of the cupric bis 8-hydroxyquinoline 5:7 disulphonic acid salt of tetradiethylamine for this purpose has been examined by Cunningham (62) who claims satisfactory results for this material with none of the reactions at the injection site so frequently found when Cu glycinate is used. In all this work stress is laid upon the importance of chemical diagnosis of Cu deficiency before these compounds are used if the risk of causing Cu toxicosis is to be avoided. Losses of sheep and cattle from Cu poisoning appear to be on the increase, particularly from the indiscriminate use of mineral supplements containing Cu, from Cu contamination in dried milk products and from the feeding of Cu supplemented pig feeds to cattle and sheep.

The feeding of high levels of Cu to growing and fattening pigs is now commonplace in many areas following the findings of Braude and his associates (63) that the inclusion of 250 p. p. m. Cu in pig diets improved food conversion efficiency and mean growth rate up to bacon weight. Lucas et al. (64) substantiated this result but suggested that 500 p. p. m. Cu may be near the toxicity level for the pig—a marked increase in liver Cu stores was noted when dietary Cu exceeded 125 p. p. m. In studies of the possible role of high levels of Cu in producing this improved performance Dutch workers (65) have found decreases in the coliform and lactobacillus population of the duodenum in pigs receiving 250 p. p. m. Cu.

In contrast to the mostly satisfactory results obtained by European workers using 250 p. p. m. Cu in pig diets it has recently been reported from Australia (66) that this level may cause parakeratosis—good responses to Zn supplementation were observed—and sudden deaths with postmortem findings suggestive of Cu poisoning. Whether this difference is related to the nature of the diet used in these experiments remains to be determined, but it is worthy of note that most European work has been carried out using fish meal and oil seed meals as protein sources whereas the Australian workers used diets containing dried skim milk and meat meal. A further note of discord



is struck by the finding of Luecke et al. (67) that 125 p. p. m. Cu can *protect* the weanling pig against parakeratosis!

## MOLYBDENUM

A growth stimulating effect of additions of Mo to chick and turkey poult rations has been observed by Reid et al. (68). In these studies, the addition of 0.0126 p. p. m. Mo as molybdic acid to a purified soyabean protein diet containing approximately 1 p. p. m. Mo was found to cause a 13 to 19 % increase in growth in a 4 week period. Workers at Cornell (69), again using soyabean protein diets, were unable to confirm this finding but small growth responses were obtained from Mo supplementation when highly purified diets were used or after tungstate (a well known inhibitor of Mo utilization) had been added to purified casein diets containing 0.5 to 0.8 p. p. m. Mo.

In studies with lambs, using semi-purified diets containing 0.36 p. p. m. Mo and with casein as protein source, Ellis et al. (70) found that increasing the Mo content by 2 p. p. m. increased the rate of weight gain from 0.11 lb./day to 0.27 lb./day. Balance trials and *in vitro* incubation studies with rumen microorganisms indicated that Mo supplementation increased the apparent digestibility of cellulose in the rumen. These workers suggest that part of the beneficial effect of alfalfa ash in improving crude fibre digestibility and liveweight gain in ruminants fed poor quality rations may reside in its molybdenum content.

## COBALT

Since the discovery that the «pining» condition of Co deficiency in the ruminant is essentially a vitamin B<sub>12</sub> deficiency it has been found that the B<sub>12</sub> activity of blood plasma is a sensitive diagnostic aid to the detection of Co deficiency (71). Clinical signs of Co deficiency may be expected to appear when the plasma vitamin B<sub>12</sub> activity falls to about 0.2 mμg/ml. Similarly, estimation of vitamin B<sub>12</sub> in the sheep liver has been claimed to give a more reliable indication of inadequacies of Co nutrition than determination of liver Co content, such assays being capable of discriminating between animals which exhibit clinical symptoms differing in severity (72).

Evidence is accumulating which indicates that marked seasonal variations in the severity of outbreaks of Co deficiency are related to changes in rainfall and environmental temperature influencing pasture composition, «lush» growths of herbage associated with a low clover content being particularly low in Co.

The development of heavy «bullets» of cobaltic oxide baked with clay as long-term sources of Co introduced into the reticulorumen for the control of Co deficiency in sheep and cattle was reported by Marston and his colleagues in 1958 (73). Since then this technique has been widely applied, particularly in areas that are not amenable to topdressing of pastures with Co salts. It is in use not only for the prevention of Co pine but also as a means of supplying the small daily quantities of Co apparently required in the rumen to prevent the development of «Phalaris staggers» — a demyelinating disorder of sheep in Australia which apparently results from the presence of a toxic factor

present in actively growing *Phalaris tuberosa* grass. Unlike Co pine, this condition does not respond to intramuscular injections of vitamin B<sub>12</sub> and it is postulated that orally ingested Co promotes the development of microorganisms capable of detoxifying the active principle (74). A similar condition in sheep grazing Ronpha pastures has recently been reported in sheep in S. Africa (75).

Claims have recently been made that Co supplements increase the rate of gain of growing pigs. It appears likely, however, that such effects are only obtained under circumstances in which dietary vitamin B<sub>12</sub> is likely to be deficient, it being possible that a degree of vitamin B<sub>12</sub> synthesis and absorption takes place in the caecum of the pig when Co salts are included in the diet — no convincing effect of Co on performance has been demonstrated when vitamin B<sub>12</sub> supplies are adequate.

### THE DIAGNOSIS OF MINERAL DEFICIENCY

Statements of the mineral requirements of livestock are now available in a variety of publications. However, it is perhaps insufficiently stressed that many such assessments are, at best, approximations to true requirements. In Table 1 an attempt has been made to classify statements of requirement on the basis of the type of study used to establish the figures usually presented. Assessments have been divided as follows: (a) statements derived from balance experiments or experiments using mineral deficient diets supplemented with different levels of the deficient element, physiological performance being subsequently correlated with mineral supply, and (b) statements based on analyses of food materials which, in practice, usually give satisfactory performance. Such a division, although arbitrary, reflects the degree of confidence which can be placed on the stated requirement, since statements of type A are derived from work carried out under controlled conditions and in which the nature of other components of the diet is usually known. The need for such control and for information on the composition of the diet is of great importance particularly when it is obvious from recent work that interactions with protein, fibre and energy level of the diet and with other mineral components may markedly affect the utilization of many elements, particularly of Cu, Zn, Mn and other trace elements. The frequent lack of information on the nature of dietary components used in experiments to determine mineral requirements in many instances limits the use of the results to rations similar to those used in the experimental study. This shortcoming is particularly important when attempts are being made to improve livestock production in underdeveloped areas where only indigenous fodders are available and where performance is believed to be limited by a mineral deficiency. In such cases statements of requirement, considered in relation to the chemical analysis of fodders, can only be used as an approximate guide to the probability of a particular element limiting production except in the case of suspected deficiencies of Ca, P, Na and K where requirements are well known and differences in availability are not usually great.

With this in mind, what methods remain available for the diagnosis of suspected mineral deficiencies? The appearance of specific lesions such as rickets, parakeratosis or enzootic ataxia may provide a useful guide. It must be borne in mind however that the exhibition of such lesions in many cases



is dependent not only on the degree of mineral deficiency but also the rate of growth of the animal as determined by the adequacy of protein and energy supplies. Furthermore, not all mineral deficiencies are associated with characteristic symptoms—poor growth and lack of appetite are frequently the only external signs of nutritional inadequacy.

In such cases chemical analysis of blood or tissues may reveal the nature of the inadequacy. Blood analysis is frequently used in the diagnosis of deficiencies of Ca, P, Mg, Cu, Fe and Co (determined as vitamin B<sub>12</sub>) and liver analysis may be used for the detection of Cu, Mn, Co and Zn deficiencies and for Cu, Mo and Se toxicoses. Determinations of bone ash and roentgenological examinations of bone density using portable X-ray units are being used in the detection of sub-clinical Ca and P deficiency.

Diagnosis by studying enzyme activity levels in tissues is in its infancy but results suggest that such methods may be extremely sensitive. Thus cytochrome oxidase levels fall dramatically in Cu deficiency and serum glutamic transaminase activity is markedly increased in muscular dystrophy—although not completely specific such techniques often provide a simple and very rapid method of «screening» suspected deficiencies.

The most humble, but probably providing the most reliable information of all, is the feeding trial using carefully compounded diets or mineral supplements designed to reveal the nature of the deficiency by a process of elimination. It is suggested that perhaps the most profitable contribution the nutritionist could make towards increasing animal productivity in the underdeveloped areas of the world is to provide guidance in the design and conduct of such field experiments which, so often at present, are carried out with indifferent results because of a lack of knowledge of the many factors which can combine to result in nutritional deficiency states in the animal.

TABLE I  
A CLASSIFICATION OF METHODS UNDERLYING STATEMENTS OF MINERAL REQUIREMENTS

| Nutrient     | Ca | P | Mg.                   | Na | K | Mn                    | Zn | Cu | Co | Fe         | Mo | I |
|--------------|----|---|-----------------------|----|---|-----------------------|----|----|----|------------|----|---|
| Dairy cattle | D  | D | D (calf)<br>E (adult) | D  | E | D (calf)<br>E (adult) | ?  | E  | E  | E          |    | E |
| Beef cattle  | D  | D | E                     | E  | E | E                     | ?  | E  | E  | E          | ?  | E |
| Sheep        | D  | D | D                     | ?  | ? | D                     | ?  | E  | E  | ?          | ?  | E |
| Pigs         | E  | E | D                     | E  | E | D                     | D  | D  | ?  | D (piglet) | ?  | E |
| Poultry      | D  | D | D                     | E  | D | D                     | D  | E  | ?  | ?          | ?  | E |

Legend: D indicates results determined from balance trial data or on trials using deficient diets supplemented with graded amounts of limiting element.  
 E indicates «estimated» requirement based on content of element in rations found to give satisfactory performance or calculation from other data.  
 ? indicates no statement of requirement made.



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## PANEL IV

### MODERATOR.

*Dr. G. Combs.* (U. S.). We will listen now to Dr. James Hillier (U. S.) who will read a paper on the following subject: «Energy Trends and Developments in the United States», after which we will have a discussion session. After this session two more reports will be read, Dr. Zucker's (Germany) and my own, dealing with the subject «Protein-Energy Ratio: Recent Trends and Developments in the European Areas and the United States». These two papers will be jointly discussed. The two papers dealing with Aminoacids and Proteins, by Dr. Maddy and Dr. Grau (U. S.) will also be jointly discussed. Dr. Varela's paper on «Nutritional Stress Caused by Fat Addition into the Feeds» will be discussed separately.

All work within this Panel will be devoted to discussing subjects related to the energy-protein ration. These compounds are rather difficult to study and are, therefore, very interesting to the researcher, as protein energy is an essential factor in animal nutrition, protein-energy ratios having a great bearing on the efficiency of feeds used. I hope this question will be studied in all its details. Now, Dr. Hillier will start by reading his report.

### ✓ ENERGY TRENDS AND DEVELOPMENTS IN THE UNITED STATES LIVESTOCK INDUSTRY ✕

DR. J. C. HILLIER

Oklahoma State University, Stillwater, Oklahoma, U. S. A.

There appears to be several distinct trends in the practices followed in producing meat animals, that is beef cattle, sheep and swine, in the United States. While the trend in each species is slightly different than that found in the others, these overall general changes are taking place.

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Dr. J. C. Hillier, Professor of Animal Husbandry, Oklahoma State University, Stillwater, Oklahoma. Arrangements for Professor Hillier's participation in the Symposium were made by the Grain Sorghum Producers Association through the U. S. Feed Grains Council in cooperation with the Soybean Council of America and the Foreign Agricultural Service.

First, processors and consumers are wanting less trimmable fat on all market animals. Enough finish within the lean meat to give the desired eating qualities to the lean meat is highly desirable, but trimmable fat is considered objectionable by processors and consumers and is expensive to produce in the feedlot. Second, all phases involved in the production of meat animals are being geared toward definite goals, such as the production of a 90 to 100 pound choice lamb, a 210 pound meat hog, and an 800 to 1000 pound choice yearling steer. Third, there is a definite swing toward the self-feeding of complete rations in either meal or pellet form, to all species. Fourth, self-fed rations are being tailored for specific production situations, particularly from the standpoint of their energy and protein contents.

It is with these four general production trends in mind that I will discuss general feeding practices and nutrition research as far as energy levels are concerned. By and large the finished product, beef, pork or lamb, is higher in protein and lower in fat than formerly, thus, it represents less stored energy. However, meat animals are being marketed at a younger age and fattened in less time, thus requiring higher energy levels in many production situations.

## SWINE — GENERAL PRACTICES

Our goal as far as swine production is concerned, is to produce a 200 to 210 pound meat type hog in less than 180 days. The meat type pig is being bred to utilize well-balanced, high energy rations, even through the finishing stages, and still produce a carcass possessing a high ratio of lean to fat.

By and large our commercial swine rations are formulated to meet the standards set forth by the National Research Council. These call for a total digestible nutrient value of 75 percent or more for growing and finishing rations. Rations containing less than 70 percent total digestible nutrients are considered to distinctly limit the rate of gain, particularly in young pigs. Levels of fiber in the ration above 6 percent are also considered to limit the gain, particularly if the feed is not finely ground. In the feeding of young pigs, the selection of palatable feeds, low in fiber and high in energy, is given considerable attention. Greater daily feed consumption is also encouraged by the pelleting of rations containing the lower energy grains, such as oats and barley, and by arranging the feed, water and resting area so as to induce maximum feed consumption.

Some attention is also being given to the providing of an environment that will minimize the expenditure of energy for the purpose of providing body heat. There is also a strong trend toward the self-feeding of brood sows during gestation on rations that are relative low in energy and high in fiber.

## SWINE NUTRITION RESEARCH — ENERGY

Two approaches are being made in swine nutrition research so far as energy intake is concerned. Higher energy rations are being tested for pigs up to market weights on the one hand, and on the other, lower energy rations that can be self-fed to females during gestation are being investigated in an effort



to reduce embryonic mortality during this period and to have these females in a more desirable condition at farrowing. There is also some work being done on reducing the energy intake of pigs approaching market weight in an effort to improve the lean to fat ration of the carcasses produced.

## FOR GROWING — FINISHING PIGS

So far as growing and finishing swine are concerned, a high rate of gain is dependent upon a high daily energy intake. Several approaches have been made toward improving the daily energy intake. The first, of course, is the providing of a nutritionally adequate ration, one result of which is improved feed intake. Second, the use of only palatable, high energy feeds or combination of feeds is indicated. Third, the pelleting of the lower energy grains or feeds to increase the energy per unit volume is being tested and fourth, the use of added fats to further increase the caloric value of rations has been given consideration.

Since much of the discussion in this paper will be in terms of total digestible nutrients (TDN), it might be well to indicate something about the caloric value of TDN. Swift, 1957, determined the TDN and digestible energy (DE) values on 312 samples of feed. He found the mean value to be 1999.4 Calories per pound of TDN. Therefore, to convert TDN to Calories of DE, simply multiply the pounds of TDN by 2000. This factor appears to hold for swine as well as for sheep and cattle.

Dinusson et al., (1953) has shown that such grains as oats and barley will not support maximum gain in growing pigs if feed in meal rations. Pelleting improved the rate of gain on barley rations by 12 to 14 percent and the efficiency by 8 to 17 percent as compared to the gain produced by identical rations fed in meal form. With the ground meal rations, 3.04 pounds of TDN was required to produce a pound of gain, whereas, only 2.52 pounds of TDN was required when the ration was pelleted. Dinusson et al. (1957) stated that pulverizing the barley minimized the effects of high fiber and increased the palatability and that pelleting reduces bulkiness and reduces waste. They further state that pigs tend to consume a ration so as to obtain a given amount of energy rather than on the basis of the total pounds of ration.

On the other hand, pelleting rations composed of high energy grain such as corn has had little effect on the daily feed intake or the rate of gain on growing and finishing swine. This is indicated by the work of Jensen et al. (1959). Rations composed largely of corn, barley or grain sorghum were self-fed in both pellet and meal form. Pelleting improved rate of gain over that produced by the meal rations by 22 percent in the case of barley, and 8 percent in the case of grain sorghum. No improvement in rate of gain was obtained from pelleting the corn ration. Pigs consumed 15 percent more feed daily when the barley ration was pelleted than when it was fed in meal form. Hillier and Martin, (1959) found no advantage in pelleting a complete ration composed of grain sorghum and supplement as compared to feeding the same ration in meal form. Also, no advantage was found for the pelleting of the ground grain only when it was fed free-choice with a protein, mineral, vitamin supplement.

Conrad and Beeson (1958) fed mixed rations of ground corn and supple-

ment and ground ear corn and supplement in pellet and meal forms. The ground corn ration contained 2.6 percent fiber while the ground ear corn ration had 7.2 percent fiber. Pigs on the low fiber rations gained significantly faster than those on the high fiber ration. Pelleting did not improve rate of gain on these rations significantly, but did cause a significant improvement in feed efficiency.

Hoefler et al. (1959) fed pigs during the finishing period on rations in which the grain portion was composed of either corn or barley or corn and cob meal. These rations contained 76.8, 74.9 and 71.4 percent total digestible nutrients. The pigs on the corn and barley rations (76.8 and 74.9 TDN) gained significantly faster on less feed per unit of gain than those on the corn and cob meal ration (71.4 percent TDN).

Hoefler et al. (1958) fed growing-finishing pigs on three rations in which the grain portions were all corn, 80 percent corn and 20 percent oats, and 60 percent corn and 40 percent oats. These rations were fed in both meal and pellet form. Pelleting improved the rate of gain significantly —10, 12 and 28 percent respectively for the rations in the order listed above. The rates of gain on all three rations in pellet form were almost identical. Compressing the feed into pellet form resulted in the following percentage increases in weight per quart; corn ration—20 percent; corn plus 20 percent oats—23 percent; and corn plus 40 percent oats—43 percent. In the case of the ration containing the highest percentage of oats, pelleting improved the average daily feed intake about 0.5 of a pound per day.

It is generally recognized that swine tend to consume more of a low energy ration than of a high energy ration if the two are self-fed in the same form, thus the daily energy intake will not be in direct relation to the caloric density of the ration they are receiving. Bohman et al., (1955) found at slaughter that the weight of the stomach and large intestine of pigs receiving a ration composed of 50 percent alfalfa meal was increased by 22 and 32 percent respectively, as compared to the weight of these organs from pigs fed no alfalfa meal.

## THE ADDITION OF ANIMAL FATS

Several pieces of research have been conducted on the value of inedible animal fats in swine rations. Hillier, (1953) fed rations containing 1.4, 3.5, 7.6 and 11.5 percent fat. The three higher levels of fat being obtained by the addition of beef fat to the basal ration. Pigs on the highest level gained about 11 percent faster than those on the lowest level on approximately 18 percent less feed per unit of gain. Carcasses from pigs fed on the high fat ration were shorter and fatter at slaughter and contained about 3 percent more fat than those on the lowest level.

Hillier et al., (1951) attempted to spread the caloric value of rations by adding 12.5 percent rendered beef fat to build up the caloric value of one ration and 20 percent ground corn cobs to another ration, to increase the fiber and reduce the energy value of this ration. Pigs on the high energy ration gained 13 percent faster on 43 percent less feed. Carcasses from the hogs fed the high energy ration were significantly fatter at slaughter. Similar results were obtained from a second trial in which prairie hay was used to build up



the fiber content of the ration instead of ground corn cobs. In these studies, each one percent increase in the fat content of the diet caused a reduction in the feed required to produce 100 pounds of gain of six pounds, or 1.6 percent.

Heitman, (1956) added 5 and 10 percent rendered fats to a basal ration. He found that the pigs fed the ration containing 10 percent added fat gained significantly faster and produced significantly fatter carcasses.

Perry et al., (1953) added varying levels of fat from 1 to 10 percent to a basal ration which contained 4.5 percent fat. The replacement of as much as 10 percent corn with lard in these growing-finishing rations did not result in an increased rate of gain. This result may be partially explained by the fact the pigs on the high fat levels were consuming less total rations and a ration of lower protein content than those on a low fat ration, thus protein may have been a limiting factor.

Kropf et al. (1954) added inedible fats to swine rations at varying rates. He found that the addition of 10 percent beef fat did not increase the rate of gain significantly, but did reduce the feed required per unit of gain. The replacement value of the added fat averaged 115 percent of that corn.

## TO IMPROVE CARCASS MERIT

While most research has been directed toward producing the most rapid and efficient gain possible from birth to market, some attention has been given recently to the influence of daily energy intake on the characteristics of the carcass produced.

Crampton et al. (1954) full-fed pigs to 110 pounds and then restricted the energy intake during the finishing period. Pigs on the restricted ration gain correspondingly less in winter than in summer. The feed efficiency was about the same for the fullfed and restricted groups regardless of the season in which they were fed. A reduction in growth rate of about 25 percent was required to reduce carcass fatness significantly.

Merkel et al. (1958) fed a ration containing 75 percent total digestible nutrients until the pigs reached 125 pounds. From this point on, rations containing three levels of energy were used (78-69 and 62 percent TDN). The fiber content of these rations varied from 2.8 to 18.1 percent. The results indicated that the level of crude fiber in the ration influenced the rate of gain more than the total digestible nutrient content. Pigs tended to compensate for the lower energy rations by consuming more feed. Differences between treatments were not significant when the crude fiber levels were less than 10 percent.

Merkel et al. (1958) also found that the viscera from the pigs fed the high fiber rations was significantly heavier than from pigs on the high energy ration. Pigs fed the lower energy, higher fiber rations had significantly less backfat than those on the high energy rations.

Hochsteler et al. (1959) studied the influence of rations containing various levels of fiber on growth and carcass characteristics on swine. The inclusion of either 20 percent wheat bran, or 20 percent alfalfa meal in the ration caused a significant reduction in backfat thickness on the carcasses produced.

Noland et al. (1960) fed rations containing 950-1050 and 1200 calories of productive energy per pound to pigs from weaning to a weight of 200 pounds. Although the feeding of increased energy levels did not result in significantly faster gains, carcasses from the pigs fed the highest energy levels were significantly fatter than those fed the lower energy rations.

## ENERGY LEVELS ON REPRODUCTION

Zimmerman et al. (1960) found that flushing gilts for intervals of 6, 10 or 14 days produced a greater increase in ovulation rate from one estral period to the next, than occurred in unflushed gilts. There was a tendency for the ovulation response to increase with greater length of the flushing period. Gilts fed glucose in addition to the basal ration for two weeks prior to ovulation shed a greater number of ova than gilts receiving the basal ration only. Gilts fed lard at 150 percent of the caloric intake of the glucose exceeded the ovulation rate of those on the control ration by 4.1 ova.

Haines et al. (1959) studied the influence of two levels of energy intake on attainment of puberty, ovulation rate and embryonic mortality. One group of gilts was limited to 50 percent of the energy intake of a full-fed group. The limited-fed gilts averaged 217 days of age and 160 pounds at puberty. Full-fed gilts averaged 195 days of age and 196 pounds at first heat. Limited-fed gilts ovulated 9.9 ova at first heat compared to 12.4 ova for the full-fed gilts. At the second heat period, these gilts ovulated at the rate of 10.8 and 13.8 ova. Gilts sacrificed at 25 days of gestation had ovulated at the rate of 11.1 and 12.7 ova at the second heat period for the limited and full-fed gilts respectively. Limited-fed gilts farrowed an average of 8.7 live pigs as compared to 9.0 live pigs for the full-fed group. Mortality during the entire gestation period amounted to 20.1 percent for limited-fed gilts and 31.8 percent for full-fed gilts. Results of this test indicate that restricting the energy intake delays puberty, depresses ovulation rate, but decreases embryonic mortality. On this basis it appears that gilts should be well fed for high ovulation rates, but limited-fed during gestation to attain higher embryonic survival. This is in agreement with the work of Robertson et al. (1951), Self et al. (1955) and Gossett and Sorenson (1959).

## BEEF CATTLE — GENERAL PRACTICES

The goal as far as a product from beef cattle is concerned is the production of an 800 to 1000 pound yearling, grading choice. By and large this is the product of good beef breeding and either full feeding in dry-lot from weaning or wintering and grazing the animals for one season before placing them on full-feed in dry-lot. In either case, high energy feeds are required during the finishing phase to impart the desired eating qualities in the beef. Even though consumers desire less trimmable fat on their beef than formerly, they still want the eating qualities imparted by concentrated feeding. The problem is to obtain these eating qualities in beef without an excess of trimmable fat. The marketing of younger and lighter weight cattle is helpful in this regard.



The increased pressure for lighter weight, high quality beef is causing feeders to turn toward «hotter rations», that is, a higher proportion of concentrate to roughage.

For the past several years, concentrates such as corn and sorghum grain have provided TDN at less cost per unit than has the roughages, if one considers cost of handling and processing the two types of feed. The need for rapid fattening of cattle at a light weight and the relative economy of concentrates has caused feeders to use rations as high in concentrate feeds, and as low in roughage as are practical. Furthermore, rations containing a high percentage of concentrates are easier to process and deliver to the feeders mechanically than those containing a large percentage of roughage.

It is reported by Blair (1960) that in the state of California 75 percent of the commercial feeders are using high energy or «hot» rations. This is probably equally true of the commercial feeders in other states as well. Mr. Blair states that the cattle are started on rations containing 42 percent concentrate and later shifted to 72 percent concentrate and finally up to 90 percent concentrate for finishing.

### CONCENTRATE TO ROUGHAGE RATIOS

Pope et al. (1956) compared the performance of steers and heifers self-fed on rations containing three concentrate to roughage ratios. These ratios were 50:50, 65:35 and 80:20. The concentrates used consisted of milo, cottonseed meal and molasses while equal parts of chopped alfalfa hay and cotton-seed hulls constituted the roughage used. Greatest gains were made by steers on the 65:35 ratio and by heifers on the 50:50 ratio. Calves on the 80:20 ratio consumed only slightly more grain daily than those on the 65:35 ratio. The 80:20 ratio appeared to be the least palatable for there was some attempt to sort out the roughage and leave the concentrate. There was very little difference in the time required to reach market or the slaughter grade of these cattle. The estimated TDN values were 61.56, 66.46 and 71.27 for the concentrate to roughage ratios of 50:50, 65:35 and 80:20. The corresponding estimated net energy values were 55.7, 61.9 and 68.0 thermes per pound of ration.

Keith et al. (1955) fed concentrate to roughage ratio ranging from 1:3 to 4:1 to steers on an individual basis. The average daily gains were not consistently different among ration treatments, however, there was a general trend toward increased rate of gain as the proportion of concentrate in the mixture was increased. The total feed required per 100 pounds of gain decreased as the concentrate to roughage ratio moved from 1:3 to 4:1. In earlier work, Keith et al. (1952) concluded that the ideal ration for steer calves contains about equal parts of concentrate and roughage and that yearling steers appear to have the ability to consume and utilize higher levels of concentrates.

Dowe et al. (1955) found that a ration consisting of two parts concentrate and one part roughage resulted in the most rapid daily gains. The total daily feed intake decreased as the concentrate to roughage ratio increased. The concentrate to roughage ratios in this study ranged from 1:1 to 5:1. Based on the result of these tests a minimum roughage allowance to 0.60 and a

maximum of 0.95 pound (air dry basis) for each 100 pounds of live weight was suggested. These workers suggest that when roughage is cheap and grain expensive the 1:1 ratio can be used economically with satisfactory results, however, with cheap grain and high priced roughage the 4:1 or 5:1 ratio might be most desirable. It is of interest to note the packers appraisal of cattle fed on so wide a variation in concentrates to roughage ratios for a uniform period of time. During the four trials (28 lots of cattle) the variation of price between lots and within seasons ranged from 0.0 to \$1.50 per hundred pounds.

## PELLETING BEEF CATTLE RATIONS

Pelleting high roughage rations has been shown to increase rate of gain, feed intake and feed efficiency of cattle in numerous experiments (Webb et al. 1957; Meyer et al. 1959; Weir et al. 1959; and Wallace and Hubbert, 1959). With high concentrate rations, several studies have indicated little or no improvement in rate of gain or feed intake from pelleting (Menzies et al. 1957; Perry et al. 1959; Beardsley et al. 1959; and Hartman et al. 1959). Pelleting high roughage rations appears to have little effect on the apparent digestibility of the various nutrients (Esplin et al. 1957; Lindahl and Reynolds 1959; and Meyer et al. 1959). There appears to be a slight advantage in yield and grade of the carcass in favor of pelleted rations as has been reported by Weir et al. (1959) and Perry et al. (1959).

McCroskey et al. (1959) fed rations containing concentrate to roughage ratios of 1:4 and 4:1 in both meal and pellet forms. Ground grain sorghum, cottonseed meal and molasses were the source of concentrate and equal parts of chopped alfalfa hay and cottonseed hulls made up the roughage. These rations produced average daily gains as follow: 1:4 ration pelleted 2.33; 4:1 ration loose 2.26; 4:1 ration pelleted 2.05 and 1:4 ration loose 1.89. Average daily gains on the 1:4 ration were increased 19 percent by pelleting, whereas, pelleting caused a reduction of 10 percent in average daily gains on the 4:1 ration. Pelleting the high roughage ration resulted in a 10 percent increase in daily feed intake; whereas, a 12 percent decrease occurred when the high concentrate mixture was pelleted. In a second trial, McCroskey (1960), pelleting the 1:4 mixture increased the average daily gain by 21 percent, whereas, pelleting the 4:1 mixture had little effect on rate of gain. Average daily intake was increased by 19 percent on the 1:4 ration by pelleting, whereas, pelleting the 4:1 ration decreased daily intake slightly.

## SHEEP — GENERAL PRACTICES

Our market demands are for a lamb weighing 100 pounds or less and grading choice. Many lambs go to market directly off the ewe at the time they are weaned. Those that do not reach the desired weight or finish at weaning are either fattened by grazing on wheat pasture or fattened in dry-lot. Obviously it is the dry-lot phase we would be most concerned with in this



discussion. Such lambs are started on feed weighing 70 to 75 pounds and marketed at weights around 100 pounds. The fact that feeder lambs now average 10 to 15 pounds heavier than they did some 15 years ago means that the feeder has less weight to put on lambs and much less time to do it in.

## CONCENTRATE TO ROUGHAGE RATIOS

Cox (1948) studied physical balance as a factor in determining the efficiency of feed utilization by fattening lambs. Concentrate to roughage ratios of 35:65, 45:55, and 55:45 were used. On the average, the best results were obtained from the 45:55 ratio, with the 55:45 in second and the 35:65 ratio last. Cox concluded that an optimum physical balance existed in rations for lambs and that as a bulky ration was made more concentrated, gains and feed utilization by lambs increased up to a certain level. Further increases in concentration of the ration resulted in lower gains and efficiency.

Using a pelleted ration, Neal (1955) found that lambs performed best on a 40:60 concentrate to roughage ratio. Lambs fed this ratio out-performed those on 30:70 or 50:50 ratios of concentrate to roughage.

Hopson et al. (1960) conducted metabolism trials and made the necessary calculations to correlate TDN and DE (total digestible nutrients and digestible energy) values obtained from these lambs. The DE and TDN values for the various concentrate to roughage ratios were: 20:80 ratio — 57.2 DE, 52.9 TDN; 30:70 ratio — 65.7 DE, 60.3 TDN; 40:60 ratio — 66.7 DE, 61.8 TDN and the 50:50 ratio 67.8 DE and 61.2 TDN. It is interesting to note that the DE and TDN values increase sharply from a ration of 20:80 to 30:70 but increase at slower rate from this point on. The TDN values were actually slightly lower for the 50:50 ratio than for the 40:60 concentrate to roughage ratio.

## SUMMARY

As livestock rations are being compounded to more nearly meet the protein, mineral and vitamin requirements of livestock, the full influence of energy in the ration is being realized. With our present ideas on levels of other nutrients, it appears that growing and finishing swine are most efficient on rations containing around 75 percent TDN. Pigs compensate for somewhat lower energy rations by consuming more feed. Generous levels of energy promote ovulation rate in gilts, but embryonic survival is improved by restricting the energy intake during gestation.

Cattle appear to be able to use a wide range of energy levels satisfactorily, giving the feeder considerable opportunity to select concentrate to roughage ratios that he believes will best fit the economic conditions prevailing. Concentrate to roughage ratios from 1:4 to 4:1 have given fairly satisfactory performance. Corresponding TDN values for those ratios are about 61 to 71 percent. Pelletizing high roughage rations for cattle improves their value materially, but the pelletizing of high concentrate ratios does not appear to be helpful. With lambs, concentrate to roughage ratios between 45:55 and 55:45 appear to give the best performance. Pelletizing the entire ration tends to improve the lower energy rations more than higher energy rations.

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## DISCUSSION

MODERATOR. Thank you very much, Dr. Hillier, your paper has been a very interesting one. Now we will start the discussions.

Dr. Robinson (Ireland). I congratulate Dr. Hillier on his most interesting

report. We are specially interested in the subject treated because of the economy it represents for our country to obtain the maximum amount of energy.

Our results coincide with the speaker's regarding high fibre rations; probably this is due to a greater growth of the organs. Nevertheless, practical difficulties are being encountered as pigs, for instance, are affected by the addition of fibre in the diet. I would like to know how do you determine carcass quality of pigs fed fibre, on the basis of fat content.

*Dr. Hillier* (U. S.). According to our research work we can say that we do not produce better pigs by using high fibre foods, but only that we find it more beneficial to do so. Regarding characteristics of the slaughtered animal I think we must reduce daily gain by about two pounds in order to obtain a difference in the final products.

MODERATOR. Thank you very much, Dr. Hillier. If there are no more questions on this subject, we will proceed to the next report. Mr. Zucker, please.

## PROTEIN-ENERGY RATIO:

### RECENT TRENDS AND DEVELOPMENTS IN EUROPEAN AREAS

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As in other fields, progress in animal production is often brought about by a complex interplay of seemingly unrelated developments and discoveries. This is well illustrated by the development of protein-energy ratios as a means for the most efficient use of feed energy.

The liberal use of feed ingredients high in energy, such as corn and fats, was formerly limited by the necessity to include ingredients of comparatively low energy content to secure an adequate intake of various dietary essentials. At the same time, when vitamins and other micronutrients and feed additives became available in concentrated form, stabilized fats became available too, thus permitting the formulation of high energy rations.

With high energy rations, quantity and quality of protein became necessarily an important limiting factor.

Mainly for this reason, energy-protein ratios have received increasing attention in recent years. Research work on protein-energy ratios — especially that conducted in the United States — has yielded a wealth of practically applicable results. By and large these results verify a physiological phenomenon of general validity: namely, that *ad libitum* feed intake is predominantly regulated by energy concentration.

Consequently, daily intake of the various nutrients depends on the caloric density of the feed. Levels of nutrients (such as protein) should therefore be put in relation to energy concentration rather than to «feed» as such.



## LIMITATIONS TO THE APPLICATION OF PROTEIN-ENERGY RATIOS

The physiological phenomenon of regulating feed intake by satisfying the need for energy is not limited to poultry. It applies to swine and cattle as well. But one of the practical limitations for applying this principle becomes apparent when maximum energy intake is made impossible by physical properties of the feed. Bulky rations of comparatively low digestibility are therefore often not consumed according to energy need. This applies especially to ruminant rations. In such cases, protein-energy ratios as determined with more concentrated feedstuffs cannot be applied.

Feeding techniques may also influence the applicability of protein-energy ratios. Handfeeding of swine according to a fixed scale, as it may be desirable for carcass quality and feed conversion, may result in optimum protein-energy ratios different from those determined under *ad libitum* feeding. In the case of restricted feeding of growing-finishing swine, protein-energy ratios may even become meaningless. Instead, one prefers to specify the desired daily energy intake plus the daily requirement for protein and amino acids.

A physiological approach to the concept of protein-energy ratios calls for proper definitions and measurement units. Net energy—be it productive calories as determined by FRAPS, or therms or starch units—does have the advantage that the heat increment as a source of variation is excluded. Metabolizable energy values, on the other hand, can be more easily determined and seem to be better reproducible.

In the case of protein, we have a more complicated situation, at least in the non-ruminant, since we are dealing with several distinctly different single nutrients, the amino acids. Where little variation in proteing quality is encountered, for instance with methionine-supplemented corn soy rations, the influence of protein-energy ratios on performance is quite reproducible.

But in order to achieve valid estimates over a wide range of energy and protein concentrations including various sources of protein, single amino acids must be related to energy concentration. This approach has already been used by some research workers. But until these relationship have been worked out sufficiently precise for broad practical application, protein-energy ratios as used so far are most valuable as a tool to achieve maximum efficiency from the available energy- and protein sources.

## CHANGES IN APPARENT PROTEIN REQUIREMENTS

About 30 years ago, the protein requirement for maximum growth of weaning pigs was estimated to be well above 20 %. Today, in rations of about the same caloric density, 16 % protein is generally considered adequate. Similarly, recommended daily protein intake figures or protein levels for growing-finishing swine have been lowered considerably. LEHMANN, whose work has influenced several European swine feeding systems, recommended for instance a minimum of 300 gms of fishmeal and tankage (180 gms protein) daily with grains *ad libitum*. Using the same feeding technique, about 220 gms of protein concentrates (130 gms protein) seem to be sufficient today.

There is little doubt that many older protein requirement studies were

confounded with some non-protein effects, such as from minerals and vitamins. The same reason may partially account for the over-estimation of the value of animal protein sources in older ration recommendations.

The lowering of protein recommendations for swine has resulted from balancing rations with B-vitamins and minerals according to the requirements and from balancing protein sources better to satisfy amino acid requirements. In addition, the quality of some protein sources has been gradually improved by better processing techniques, as it is especially the case with soybean oil meal and with some fishmeals.

In broilers, the same factors have become effective, but they have not resulted in a decrease in protein levels. This can be explained by a spectacular increase in genetic production ability and by increased energy density of rations.

In laying rations, where caloric density has not changed much over recent years, there is a general trend for a gradual decrease in protein recommendations. Maximum performance can apparently be achieved with protein levels of 14 % and even lower, when amino acid requirements are met and feed intake, and thereby protein intake, is not inhibited by high temperatures.

Not much change has occurred in protein recommendations for ruminants, where proteins are «equalized» by rumen micro-organisms to a uniform biological value of about 65-70 and, in addition, the contribution of B-vitamins and minerals from protein feeds is of little or no significance. Some new findings on the beneficial effect of lysine under certain conditions await further evaluation.

Regarding the changes in apparent protein requirements during the last decade, one must always keep in mind that precise assessment of protein needs has become possible only since adequate mineral-, vitamin- and even unidentified factor-intake could be secured independently of protein feeds.

The correction of the general overestimation of protein requirements, caused by interference of these factors, has shown lower requirements than formerly estimated. In addition, increased knowledge on protein quality and amino acid needs tends to lower requirement figures.

On the other hand, increased performance as achieved by genetic, nutritional and environmental factors raises protein requirements. So does increased energy concentration, if protein requirements are expressed as protein levels in feed.

Finally, more adequate performance criteria than «liveweight» or «percent egg production» do also support higher — or better balanced — protein needs. The Danish research on the influence of protein nutrition on pork quality demonstrates this point. It is an example for the contribution which protein nutrition can make to satisfy the growing consumer demand for food rich in protein and low in calories.

## SOME ECONOMICAL ASPECTS

Animal nutrition research is, and always has been, greatly influenced by economic conditions. Protein research has certainly always been stimulated by the fact that protein of high quality in concentrated form is expensive. Thus, rations are usually formulated to meet minimum protein requirements rather than to waste a lot of surplus protein for energetic purposes.



Therefore, emphasis in determining protein-energy ratios is usually placed on the widest protein-energy ratio tolerated without a decline in production.

A reason for economizing on protein is not only the comparatively high cost per unit of protein, but much more the fact that the unit of energy is usually quite expensive in typical protein concentrates, compared to the cost per unit of energy from grains and other common energy sources.

Considering the title of this paper, it may be interesting to point out that this situation, which is more or less resulting from the world wide demand and supply picture, does not prevail in all countries.

In Western Germany for instance, which has the greatest consumption of protein feeds in Europe, the unit of TDN from soybean oil meal is less expensive than the unit of TDN from the various feed grains. Recently, even TDN from fishmeal have been cheaper than TDN from grain! Under such circumstances, there is little incitement to economize on protein. Consequently, protein is being used quite liberally in commercially mixed feeds.

This situation is due to the high grain prices, which result from tariffs and import regulation set up to protect the home grown grain crops, while at the same time protein feeds are traded at world market price.

With comparatively cheap protein, there is of course also less reason to use urea, synthetic amino acids or any measures which help in saving protein.

At the same time, high grain prices make the use of inedible fats very economical. Accordingly, least cost rations formulated by linear programming should come out with high amounts of soybean oil meal, high levels of fat, cassava meal and molasses, but with little or no grains, if no upper restrictions are put on energy and protein.

Protein-energy ratios should therefore have little practical importance under these conditions. In practice, the facts do not quite behave according to theory. Even with cheap protein there is still, as in most countries, a disproportion between the overall disappearance of feed energy and feed protein. The high increase in the use of protein feeds in Germany in recent years is mainly due to the development of the feed industry.

Where commercially mixed feeds are used according to recommendations, there is often a more than adequate protein intake. On farms where no commercial feedstuffs or mixed feeds are used, protein deficiency is still very common as the limiting factor for production.

In addition, expensive sources of animal protein — such as fish meal and skim milk — are still used in unnecessary high amounts. That is true for mixed feeds too, because the feedlaw specifies levels of animal protein for certain types of feed.

Animal protein sources — especially fishmeal — do still have a big share in European protein feed consumption. Western Germany alone uses more than 250 000 tons of fishmeal annually, not much less than the U. S., where several times as many animal units are fed. In the U. S. with its animal industries of ever increasing volume and efficiency, the increase in consumption of protein feeds during the last 2 decades has almost entirely been due to soybean oil meal!

## CONCLUSIONS

Trends and developments in energy and protein nutrition in Europe do not differ basically from those in the United States. European broiler operations for instance, which have developed fast in recent years, are using rations very similar to those recommended in United States. A similar development has begun or can be expected in egg production.

In swine, feeding techniques in Europe favor various forms of restricted feeding, which places emphasis on sufficient protein of high quality to secure optimum feed efficiency and carcass quality.

In dairy and beef production, high lactation performance and increased demand for high quality beef favor concentrate feeding, thus causing increased energy intake which in turn necessitates increased protein intake.

The price ratios of various feedstuffs have a pronounced effect on the use of ingredients and overall protein-energy ratios are influenced accordingly.

So do the prevailing feedstuffs influence protein-energy ratios: grains lower in caloric value than corn, such as barley, are used in Europe to a great extent.

But since nutritional requirements in the U. S. and Europe are identical for all practical purposes, and since the desired product quality is similar too in both areas, one should expect that increasing production efficiency will finally lead to almost identical concepts in practical feeding too.

## PROTEIN-ENERGY RATIO: RECENT TRENDS & DEVELOPMENTS IN THE U. S.

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The method of expressing nutrient requirements for different classes of poultry as amounts per pound of feed rather than amounts required for maintenance, activity, growth, and production functions, leaves much to be desired. Though convenient, in application those factors which may influence the level of feed consumption result in direct changes in nutrient intake. If a feed is adequate in essential nutrients, energy concentration largely determines the amount of feed which will be consumed under specific conditions, provided that volume, texture, palatability, and accessibility of the feed are not first limiting. Consequently, it is desirable to relate nutrient requirements of each



specific class of poultry to the energy potency of the feed, unless considerable margins of safety are provided.

Since by far the greatest part of feed ingredient cost is used to provide energy and protein, efficient use of these components is usually imperative for best economy. Poultry feeds may vary appreciably in energy potency; particularly, when low fiber high-energy grains and stabilized fats are available. Such high-energy feeds require correspondingly higher level of «effective» protein in order to maintain adequacy.

*Energy-protein ratios.*—Accordingly, ratios of energy to protein were suggested for use in formulation of practical rations (1) in 1955. These ratios were termed «calory-protein ratio» (C/P ratio) and were intended to serve as a guide in maintaining the most satisfactory balance of energy and protein for efficient production. These ratios were based on studies using practical type rations composed largely of corn and soybean meal protein, supplemented with methionine. The term «C/P ratio» is defined as the Calorie content per pound of feed divided by its percent protein. These may be expressed as a function of Productive Calories (PC/P) or of Metabolizable Calories (MC/P). Numerous studies have been conducted in the past few years with growing chickens (1-15), turkeys (16-24), and laying hens (25-31) on energy-protein balance. Suggested Calorie-protein ratios for poultry are given in Table 1. Such ratios have been used widely in the U. S. as a guide in practical ration formulation.

TABLE I

SUGGESTED CALORIE/PROTEIN RATIOS\* FOR POULTRY

|                                 | Metabolizable | Productive |
|---------------------------------|---------------|------------|
| Broiler starter (0-5 wks.)      | 60-65         | 42-45      |
| Broiler finisher (after 5 wks.) | 69-75         | 48-53      |
| Chick starter (0-8 wks.)        | 63-66         | 44-46      |
| Chicken grower (8-18 wks.)      | 77-86         | 54-60      |
| Layers, 50 % production         | 91-94         | 64-66      |
| Layers, 70 % production         | 84-87         | 59-61      |
| Layers, 90 % production         | 80-83         | 56-58      |
| Turkey starter (0-6 wks.)       | 40-44         | 28-32      |
| Turkey grower (6-12 wks.)       | 55-60         | 38-42      |
| Turkey grower (12-18 wks.)      | 70-74         | 48-52      |
| Turkey grower (18-24 wks.)      | 85-90         | 60-65      |
| Turkey finisher                 | 100-105       | 70-72      |
| Turkey breeders                 | 86-91         | 60-64      |

\* C/P ratio is defined as  $\frac{\text{Calories per lb.}}{\% \text{ protein}}$

Since protein contributes by supplying amino acids to the animal, it becomes obvious that changes in amino acid make-up or quality of the protein will materially influence the optimal energy-protein ratio. The ratios suggested in Table 1 apply to feeds composed principally of corn and soybean meal, with small amounts of animal protein. Any change in protein source, leading to a critical difference in amino acid make-up of the protein, would obviously influence the «effectiveness» of the protein. Addition of methionine to corn-soybean oil meal rations improves the quality and «effectiveness» of the protein for poultry, thereby permitting the use of rations with wider C/P ratios. Accordingly, differences in protein quality must be considered in the application of C/P ratios in practical ration formulation.

In addition to protein quality, any factor which modifies the bird's need for energy in a manner not quantitatively proportional to its effect on the requirement for amino acids, and vice versa, may be expected to result in a change in the optimal energy-protein relationship. Absolute dietary nutrient requirements may be expected to vary with differences in rate of growth or production, body size, activity, temperature, changes in body composition, age, differences in intestinal microflora, and other factors. A change in the need for amino acids may be quite different from that for energy. For example, such would be the case with increased activity and cold ambient temperature where energy requirement is increased with little, if any, change in the need for protein.

Part of the differences in requirements associated with stage of growth and function is considered by expressing requirements according to type of poultry by age group, i. e. for starting broilers, finishing broilers, laying hens, breeding hens, etc. In this way, useful guides can be established for practical feed formulation.

*C/P ratio and body composition.*—In addition to energy concentration, the protein adequacy of the ration also has been shown to influence feed caloric intake (1, 32-34). In work at the University of Maryland, isocaloric rations containing different levels of protein and isonitrogenous rations containing different levels of energy were used to provide a range of productive calorie-protein ratios ranging from 35 to 70:1. All rations had sufficient energy density to insure that capacity would not limit feed consumption. As the C/P ratio was widened, a 2-1/2 fold increase in the body fat content (from 5.6 % to 14.2 %) was observed with relatively little difference in rate of gain. There was no effect on rate of gain when the C/P ratio was widened from 35 to 49 despite the fact that 68 % more fat was present in the carcass of chicks fed the C/P 49 rations than was present when the C/P 35 ration was used. By merely reducing the level of protein without altering its amino acid quality, the body fat content was increased from 5.6 to 9.4 %. The energy content of the carcass also was varied from 770 to 930 Calories per pound before differences were observed in rate of gain. Further increase in carcass energy and fat content and decrease in moisture content were observed with rations having wider C/P ratios.



The positive correlation between C/P ratio and body fat content indicates that the chick is able to increase appreciably its energy intake in an effort to obtain sufficient protein. In this way, the growing chick can overcome, to some extent, «protein deficiency stress» as measured by rate of gain, although the increase in energy intake is reflected in higher fat content of the carcass. If isocaloric rations are used, this over-consumption of energy results in poorer feed conversions.

The use of rate of gain as the only measure of response in studies of protein and amino acid requirements without determining changes in body composition, makes it difficult to interpret results properly. Since lowering the level of protein in relation to energy content causes a relative over-consumption of energy, the minimum protein or amino acid level which will support rate of gain can be considered only as that level below which the «protein deficiency stress» can no longer be overcome completely, and not necessarily the level required for an optimal nutritional state. It has been shown also that the percentage of dietary protein retained in the carcass is influenced greatly by the energy intake of the chick (35).

*Amino acid-energy relationships.*—Though C/P ratios have been extremely useful as a guide in the formulation of feeds containing similar type protein, the use of amino acid-energy ratios directly eliminates much of the concern of protein quality. Although one may consider the amino acid requirements a function of protein, and then the protein level as a function of energy, this merely establishes a relationship between the amino acids and energy content of the ration. Since it is difficult to formulate rations containing perfect amino acid balance, the author prefers the direct approach of using amino acid energy ratios as a guide in practical formulation. Obviously, one must consider all amino acids which might be critically limiting. Improvements can be expected only when the level of the first limiting amino acid(s) is increased in a ration which originally contained a sub-optimal level.

In correcting amino acid deficiencies one may 1) increase the level of the limiting amino acid or acids by supplementation if such is available, 2) substitute another protein high in the limiting amino acid(s) in place of some of the original protein in the ration, or 3) increase the total protein level sufficiently to meet the requirements of the first limiting amino acid. The latter procedure may be used successfully only when the protein quality is not too poor. It results in wasteful use of protein and usually increases the feed cost per unit of product.

Suggested minimum amino acid-energy concentrations for use in formulation of practical feeds for broilers are given in Table 2. These ratios are based on Maryland studies and N. R. C. requirements for starting chicks. In calculation of the methionine levels, corn and dehulled soybean meal (50 % protein) were assumed to contain 0.18 and 0.7 % methionine respectively.

TABLE II

SUGGESTED MINIMUM AMINO ACID/ENERGY CONCENTRATIONS FOR USE IN  
FORMULATION OF BROILER FEEDS FOR CHICKENS

| Amino Acid               | % Amino Acid ÷<br>Therms M.E./lb. |                  | Grams of Amino Acid<br>per Therm of M.E. |                  |
|--------------------------|-----------------------------------|------------------|------------------------------------------|------------------|
|                          | Starter                           | Finisher         | Starter                                  | Finisher         |
|                          | (0-4 ½ wks.)                      | (after 4 ¼ wks.) | (0-4 ½ wks.)                             | (after 4 ¼ wks.) |
| Methionine + Cystine     | 0.55                              | 0.47             | 2.50                                     | 2.15             |
| Methionine               | 0.31                              | 0.27             | 1.40                                     | 1.20             |
| Lysine                   | 0.75                              | 0.65             | 3.40                                     | 2.95             |
| Tryptophan               | 0.15                              | 0.13             | 0.70                                     | 0.60             |
| Glycine                  | 0.75                              | 0.65             | 3.40                                     | 2.95             |
| Arginine                 | 0.80                              | 0.70             | 3.65                                     | 3.15             |
| Valine                   | 0.60                              | 0.52             | 2.75                                     | 2.35             |
| Phenylalanine + Tyrosine | 1.09                              | 0.94             | 4.95                                     | 4.26             |
| Phenylalanine            | 0.55                              | 0.47             | 2.50                                     | 2.13             |
| Leucine                  | 1.09                              | 0.94             | 4.95                                     | 4.26             |
| Isoleucine               | 0.47                              | 0.41             | 2.13                                     | 1.86             |
| Threonine                | 0.47                              | 0.41             | 2.13                                     | 1.86             |
| Histidine                | 0.23                              | 0.20             | 1.04                                     | 0.91             |

NOTE: To obtain corresponding values on the basis of productive energy multiply by 1.43

Similar requirements of starting and growing turkeys have been determined in collaborative studies with U. S. D. A. and the University of Maryland for lysine and methionine as shown in Table 3, using similar corn-soybean meal type rations.

TABLE III

LYSINE AND METHIONINE REQUIREMENTS OF GROWING TURKEYS 1)

| Period,<br>Weeks | % Amino Acid ÷<br>Therms M.E./Pound |            | Grams of Amino Acid<br>per Therm M.E. |            |
|------------------|-------------------------------------|------------|---------------------------------------|------------|
|                  | Lysine                              | Methionine | Lysine                                | Methionine |
| 0-3              | 1.20                                | 0.45       | 5.46                                  | 2.03       |
| 3-6              | 1.04                                | 0.38       | 4.68                                  | 1.74       |
| 6-9              | 0.88                                | 0.33       | 4.02                                  | 1.49       |
| 9-12             | 0.75                                | 0.28       | 3.39                                  | 1.26       |
| 12-15            | 0.66                                | 0.24       | 2.95                                  | 1.09       |
| 15-18            | 0.57                                | 0.21       | 2.55                                  | 0.95       |

1) Unpublished data, Twining, USDA, Beltsville, Maryland Combs, University of Maryland, presented at University of Maryland 1960 Nutrition Conference for Feed Manufacturers, March, 1960.



It is recognized that many other factors besides protein level and amino acid balance would influence the optimal amino acid needs per unit of energy just as factors other than protein quality may be expected to influence the optimal C/P ratio. Ideally, the requirements should be calculated for each amino acid and for energy from equations designed to consider many factors, including body size, activity, temperature, level of egg production, growth rate, etc. Such an attempt has been made to estimate the absolute requirement of the laying hen for methionine and energy.

*Amino acid requirements of laying hens.*—Differences in level of egg production, egg weight, body size, temperature, activity level, feed potency, as well as protein quality and amino acid balance, lead to market variance in the apparent requirement for protein by the laying hen.

Results obtained with laying hens at the University of Maryland have permitted the partition of the requirement for methionine into maintenance, body weight gain and, egg production functions (5). This is set forth in equation 1 below. Previous work conducted at Maryland in 1941, by Byerly (36) provided an equation for the calculation of the feed requirement of laying hens considering maintenance, change in body weight, and weight of egg product. The Byerly equation has been modified to yield Calories of metabolizable energy rather than weight of feed required (equation 2).

With these two equations, one can calculate the requirements for both, methionine and Calories of metabolizable energy per hen per day for varying conditions. The temperature factor which has also been included in the modification of Byerly's equation (equation 2), is based on the data obtained by Hill (37) in which he has obtained average relative efficiencies of feeds during different seasons in relation to those predicted by the Byerly equation. To correct for temperature in a general way by season (equivalent to temperatures in Ithaca, New York), the following values are given for T in equation 2 above: 0.98 for fall; 1.05 for winter; 1.0 for spring; and 0.94 for summer.

The grams of methionine required per therm of metabolizable energy may then be calculated by merely dividing M by C as determined in equation 1 and 2 above. This can be converted into percent methionine for a specific ration of known energy content.

---

(1)  $M = 0.05W \pm 6.2 \Delta W + 5E$   
and

(2)  $C = T (1.516W^{0.653} + 3.264 \Delta W + 3.29)$

Where M = daily methionine requirement per hen in milligrams

C = daily requirement for metabolizable Calories per hen

W = average body weight per hen in grams

$\Delta W$  = average daily change in body weight per hen in grams

E = average grams of egg product per hen per day

and T = approximate temperature correction factor for each season.

TABLE IV

CALCULATION METHIONINE REQUIREMENT FOR LAYING HENS 1)  
(Per Cent of Ration)

| Season                                           | GRAMS EGG PER |       | HEN PER DAY |      |
|--------------------------------------------------|---------------|-------|-------------|------|
|                                                  | 57            | 52    | 47          | 42   |
| 1310 Calories of Metabolizable Energy Per Lb. 2) |               |       |             |      |
| Summer                                           | .295          | .288  | .281*       | .272 |
| Fall                                             | .286          | .280* | .273        | .263 |
| Spring                                           | .280*         | .274  | .267        | .258 |
| Winter                                           | .265          | .259  | .252        | .244 |
| 1425 Calories of Metabolizable Energy Per Lb. 3) |               |       |             |      |
| Summer                                           | .321          | .313  | .305        | .295 |
| Fall                                             | .311          | .304  | .297        | .286 |
| Winter                                           | .288          | .282  | .274        | .265 |
| Spring                                           | .304          | .298  | .290        | .280 |

- 1) 4 lb. hens, gaining 1 gm. per hen per day.  
 2) 920 Calories of productive energy per pound.  
 3) 1000 Calories of productive energy per pound.  
 \*) NRC requirement is .28 %.

After the methionine requirement is determined for specific conditions, one may *approximate* the levels of the other essential amino acids required by applying conversion factors based on the relative amounts of the amino acids present in egg protein. This approach has been used by Fisher (38). Using the values of Block and Weiss (39) the following conversion factors are multiplied directly by the calculated requirement for methionine: methionine, 1.0; methionine plus cystine, 1.7; histidine, 0.73; isoleucine, 2.09; leucine, 2.85; lysine, 2.09; phenylalanine, 1.76; phenylalaline plus tyrosine, 3.0; tryptophane, 0.49; threonine, 1.52; and valine, 2.24.

Using this method, the methionine needs of laying hens have been calculated for 4 pound laying hens, gaining 1 gram in body weight per day, by seasons and for different levels of production. These are expressed as percent of the ration for feeds varying in energy potency as shown in Table 4. Note their close agreement with the N. R. C. requirement of 0.28 %, which applies to feeds containing 1310 Calories of metabolizable energy (920 Calories of productive energy) per pound.

In Table 5 are presented the N. R. C. amino acid requirements for the laying hen expressed as a function of energy level. These are % amino acid level required: therms of metabolizable energy per lb. of feed. To obtain these requirements as % of a particular ration, one would merely multiply these values by the number of therms of metabolizable energy per lb. of ration.



TABLE V

EXAMPLE AMINO ACID REQUIREMENT ESTIMATES FOR LAYING HENS  
UNDER VARYING CONDITIONS

| Amino Acid               | Reference<br>Requirements<br>Adapted<br>from NRC 1) | Calculated by the Author 2)             |                      |                    |                      |
|--------------------------|-----------------------------------------------------|-----------------------------------------|----------------------|--------------------|----------------------|
|                          |                                                     | 4 lb. Hen                               |                      | 6 lb. Hen          |                      |
|                          |                                                     | 90 % Prod.<br>Fall                      | 80 % Prod.<br>Winter | 80 % Prod.<br>Fall | 70 % Prod.<br>Winter |
|                          |                                                     | % Amino Acid per Therm M. E. per Lb. 3) |                      |                    |                      |
| Methionine               | 0.21                                                | 0.22                                    | 0.19                 | 0.20               | 0.18                 |
| Methionine + Cystine     | 0.40                                                | 0.37                                    | 0.33                 | 0.34               | 0.31                 |
| Lysine                   | 0.38                                                | 0.45                                    | 0.40                 | 0.42               | 0.38                 |
| Tryptophan               | 0.12                                                | 0.11                                    | 0.09                 | 0.10               | 0.09                 |
| Leucine                  | 0.92                                                | 0.62                                    | 0.55                 | 0.57               | 0.52                 |
| Isoleucine               | 0.38                                                | 0.45                                    | 0.40                 | 0.42               | 0.38                 |
| Threonine                | 0.31                                                | 0.33                                    | 0.29                 | 0.31               | 0.28                 |
| Histidine                | —                                                   | 0.16                                    | 0.14                 | 0.15               | 0.13                 |
| Phenylalanine            | —                                                   | 0.38                                    | 0.34                 | 0.35               | 0.32                 |
| Phenylalanine + Tyrosine | —                                                   | 0.65                                    | 0.58                 | 0.60               | 0.55                 |
| Valine                   | —                                                   | 0.49                                    | 0.43                 | 0.45               | 0.41                 |

- 1) NRC Requirements  $\div$  by 1.31 (assumes 1310 Cal. M.E./lb).
- 2) Based on calculated needs for energy and methionine (see text) with % prod. adjusted to 57 gram eggs. Estimated needs of other amino acids based on methionine requirement value, considering the amino acid proportions found in egg protein. These levels permit an average daily gain of 1 gram in body weight per hen.
- 3) To obtain % of amino acid in feed, multiply by therms of metabolizable energy per pound.

For comparison, the author has computed the methionine and energy needs for 4 and 6 pound hens laying at different rates in Fall and Winter. From these data, estimates of the needs for other essential amino acids were made based on the above described method. These values apply to layers maintained in floor pens. Slightly higher values might be needed for birds in cages.

Such an approach recognizes certain of the many factors which do influence the requirement of the animal for energy and for protein independent of each other. Since feed intake is largely dependent upon energy level of the ration, and because both energy and protein constitute the largest part of the feed cost, the need for such improved approaches to the estimation of the protein and amino acid requirements for poultry appears obvious.

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## DISCUSSION

*Dr. Clausen* (Denmark). We in Denmark, when using the restricted feeding system must supply a higher protein concentration than countries feeding their pigs ad libitum. Because of this it is difficult to supply a given amount of energy regarding the aminoacids-energy ratio if we take into account that the daily protein need is a fixed one. I would like Mr. Zucker to tell us whether it would not be better to talk about pig requirements for maximum meat production, without mentioning the higher or lower feed conversion, on account of the possibility of obtaining a similar conversion with different rations which will still produce different carcasses.

*Dr. Zucker* (Germany). I fully agree with you in that talking about conversion index improvement is a rather poor point of view regarding the general sense of nutrition needs. These needs should be determined though some basic form of nitrogen retention, or something like that.

*Dr. Combs* (U. S.). Talking about poultry, I have done some research on



the effects of protein and energy intake taken from carcass composition, for the special purpose of considering determination of needs without changes in the carcass, using different rates of growth and high protein levels in the diets, comparing each diet with similar protein intakes but lower energy intake. We have been able to determine these needs for obtaining the maximum balance required by poultry within changing carcass composition.

*Dr. Zucker (Germany).* I think Dr. Combs is right. However, I would like to state that our knowledge regarding aminoacid needs for swine have been obtained mostly with pure rations, or rations differing from practical rations, specially for piglets under 70 pounds. Aminoacid content of the components of our rations are not yet sufficiently safe to determine these factors.

MODERATOR. Well, now Dr. Maddy will speak about «Amino Acids: Poultry».

## AMINO ACIDS: POULTRY

KENNETH H. MADDY

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The preceding speakers have described in detail the important relationship that exists between the levels of dietary energy and proteins. Since proteins are made up of amino acids and the nutritional value of proteins depends upon their amino acid content, it follows that energy-protein relationship are actually energy-amino acid relationships. The information obtained from protein-energy interrelationship studies has now allowed us to determine more accurately the requirements of poultry for amino acids. I would like to present some of the work that has been done on this subject and to outline the work that remains to be done in order to achieve the objective of obtaining optimum amino acid utilization in all types of poultry diets. Optimum utilization is achieved when the diet contains no surpluses or deficiencies of amino acids. When a dietary protein is ingested, it is hydrolyzed into individual amino acids and short chain peptides which are then absorbed into the blood stream and transported to the desired site of tissue protein synthesis. Protein synthesis will occur only when all amino acids required are present at the site of tissue protein synthesis at the same time. A deficiency of a single amino acid required in the formation of a protein molecule will prevent the formation of that molecule with elimination of the other amino acids and a cessation of tissue protein synthesis. The problem, therefore, of satisfying the amino acid requirements of poultry is one of supplying in the diet an adequate level of dietary protein and all other nutrients necessary for tissue protein synthesis. Since very few naturally occurring proteins can be fed to supply the quantitative requirements of the chicken, it is necessary to use combinations of proteins in the diet so that they will mutually supplement one another. The use of mixtures of proteins, however, not only leads to wasteful excesses of amino acids but also dietary proteins are added at the

expense of the higher energy carbohydrate feedstuffs. With the availability of cheap synthetic amino acids, the feed industry can better obtain optimum utilization of proteins while at the same time leaving more room in the feed bag for higher energy feed components.

The problem now, therefore, is to determine how much of what amino acids are necessary in practical diets under all types of feeding conditions. When this is known the feed man could determine what proteins to use, how much of each to use, and what synthetic amino acids are necessary to balance out the natural proteins employed. Before it is possible to determine the amino acid requirements of poultry on any specific diet, it is essential that the diet be formulated so that all other nutrients are present in excess in order to insure that tissue protein synthesis will be limited only by the level of dietary protein. Thus, it is useless to study the effect of adding methionine to a practical diet if the diet does not contain sufficient energy to support the extra growth that could result from the additional protein made available by the supplementary methionine. Although this appears to be obvious, many of the literature reports have been rendered useless because the investigators overlooked this simple fact.

In the United States the most common protein and energy supplements used in poultry rations are corn and soybean meal. Since methionine is the first limiting amino acid in this combination, it has received the most research attention and more is known concerning the methionine requirements of poultry than for any other amino acid. Furthermore, the determination of requirements of poultry for all other amino acids have been derived from studies on the requirements of poultry for methionine. Since methionine is a multi-functional amino acid, the true requirements for methionine must be determined under conditions that insure that the methionine is utilized preferentially for tissue protein synthesis rather than for satisfying non-specific metabolic functions. The interrelationship between choline and methionine must be considered since both can satisfy the bird's requirement for labile-methyl groups. Because choline is cheaper than methionine sufficient choline must be added to insure that the methionine is not being utilized solely as a donor of labile-methyl groups. Another interrelationship to be considered is that existing between methionine sulfur and inorganic sulfur.

It was first reported by Gordon & Sizer (*Science* 122, 1270, 1956) that with the chicken, part of the total sulfur requirement can be satisfied with inorganic sulfate although inorganic sulfate cannot replace the specific need for dietary cystine or methionine.

Table 1 illustrates typical feeding results obtained as a result of this dietary replacement. Not only does the addition of inorganic sulfur, as sodium sulfate, improve growth and feed efficiency of the birds, but also observed was a striking effect on feathering. The feather score is based on an arbitrary scale of units from one to four with four representing perfect feathering. It can be seen that satisfactory feathering was obtained only in the presence of sodium sulfate. The birds fed diets deficient in organic sulfur but containing adequate quantities of inorganic sulfur, feathered normally but grew at a suboptimum rate and conversely, birds receiving this cystine deficient diet supplemented with methionine or MHA (registered Trademark Monsanto Chemical Company for calcium DL-2-hydroxy-4-methylthiobutyrate) grew nearly optimally but exhibited poor feather development.



TABLE I

ADDITION OF SULFATE, METHIONINE OR MHA TO DIETS DEVOID OF INORGANIC S

| Addition to<br>Basal                        | wt<br>gain | fd.<br>gain | feath.<br>score |
|---------------------------------------------|------------|-------------|-----------------|
| None                                        | 372        | 2.84        | 1.2             |
| 0.5 % $\text{Na}_2\text{SO}_4$              | 488        | 2.70        | 3.6             |
| 0.22 % DL-methionine                        | 517        | 2.43        | 1.8             |
| 0.22 % MHA                                  | 521        | 2.41        | 2.1             |
| 0.22 % MHA + 0.5 % $\text{Na}_2\text{SO}_4$ | 617        | 2.38        | 3.8             |

(Note: 5 weeks results)

Although methionine, cystine or MHA must be added to such diets in order to obtain optimum growth, inorganic sulfur derived from sodium sulfate can substitute for a portion of this sulfur requirement. In fact, in the experiment presented here, optimum growth was obtained only in the presence of sodium sulfate. Additional studies have been conducted to show that with a cystine deficient diet, optimum growth and feed efficiency of chicks is obtained by the addition of cystine alone. However, methionine or MHA will produce optimum growth only when added in combination with sodium sulfate. These findings support the evidence that methionine sulfur is oxidized to sulfate largely through cystine.

Thus, the total sulfur requirement of the chick can be represented as shown on Figure 1. Methionine can only be supplied by dietary MHA, methionine or homocystine, and these compounds, therefore, account for about 40 % of the dietary sulfur requirement. The cystine requirement can be satisfied either by dietary cystine, MHA, or methionine, and utilizes, therefore, another 30-40 % of dietary sulfur. Lastly, the chicken will form organic sulfur compounds which are not sulfur amino acids from either methionine, cystine or inorganic sulfates. In the last few years it has been recognized that living tissues contain significant quantities of sulfur containing organic compounds that are not amino acids, principally in cartilage and connective tissues as chondroitin sulfates, hyaluronic acids, etc. It has been calculated that about 20-30 % of the total sulfur of the diet must satisfy this requirement.

With this information in mind it is now possible to determine the effect of alterations in the protein and energy levels on the requirement of the bird for sulfur amino acids. It has been reported by Almquist (*Proc. Soc. Exp. Biol. Med.*, 72, 179 (1949)) that the requirement of the chick for methionine varies more or less directly with the protein level as does arginine, lysine, and probably all other essential amino acids. Almquist has also shown that as the dietary protein level is raised, the requirement for lysine and total sulfur amino acids expressed as a percentage of dietary protein decreases. Figure 2 shows results obtained that demonstrate this effect. With the development of the calorie-protein ratio concept, it is now evident that this effect reported by Almquist occurred because the dietary energy level decreased as the protein level increased or in other words, the amino acid requirement as a percent of

protein decreased as the calorie-protein ratio decreased. If the amino acid requirements of the broiler were plotted against increasing dietary protein at increasing C/P ratios or iso C/P ratios, curves obtained would be as shown in Figure 3. Thus, it is seen that the requirement of the chick for an amino acid varies both with the energy and protein levels of the diet. Consequently, the most accurate method for calculating the amino acid requirements of the chick is to use the C/P ratio. This method of calculation first described by Gordon and Maddy (*Poultry Science*, 35, 1145, 1956) is based on actual feeding trials with broilers using both purified and practical diets at different levels of protein and energy. The relationship that has been established between the C/P ratio and the requirement of the chick for methionine is given on Table 2. These estimations are such that in a broiler starting diet

TABLE II

METHIONINE REQUIREMENT AS PERCENT OF PROTEIN  
EXPRESSED AS A FUNCTION OF C/P

| C/P RATIO | METHIONINE AS<br>% DIETARY PROTEIN |
|-----------|------------------------------------|
| 36 — 38   | 1.9                                |
| 41 — 43   | 2.15                               |
| 48 — 50   | 2.3                                |

having a C/P ratio in the range of 36 to 38, the methionine requirement of the chick is 1.9 % of the dietary protein. As the C/P ratio increases, the requirement increases as shown. The next step is to relate this calculated methionine requirement to the chick's requirements for all other essential amino acids. Actual feeding trials conducted to determine the effect of altering ratios of essential amino acids in chick rations has convinced us that the amino acid requirements of the chick as proposed by the National Research Council (NRC) best represent the ratio of dietary amino acids to maintain for optimum acid utilization. A method of determination of amino acid requirements has been developed that considers the relationship between the calculated methionine requirement at a specific C/P ratio and dietary protein level and the NRC methionine requirement. This requirement for methionine can then be related to the requirement for any other amino acid by means of the established NRC ratio of amino acid requirements. This is best described in Table 3.

TABLE III

EXTRAPOLATIONS OF METHIONINE CALCULATIONS TO OTHER AMINO ACIDS

|                                  |   |                              |
|----------------------------------|---|------------------------------|
| Predicted Methionine Requirement | = | Predicted Requirement AA (X) |
| NRC Methionine Requirement       |   | NRC Requirement for that AA  |



Knowing the calculated requirements for the amino acids, it is now necessary to determine the amount of amino acids that must be added to any particular diet in order to produce optimum performance. To do this, it is necessary to know the levels of biologically available amino acids in each feedstuff and also the effect of the dietary level of any one amino acid on the requirement of the bird for any other amino acid. A considerable amount of research on this subject is being done in many laboratories throughout the world and we believe that it will soon be possible to predict accurately the absolute requirements of the chick for each essential amino acid under all types of feeding conditions. This does not mean, however, that amino acids cannot now be used in practical diets. What it does mean is that such information will enable a nutritionist to build the protein portion of a diet with greater precision. Several synthetic amino acids are now being used in practical poultry rations with good justification and with excellent economic response. The most general application is in the use of synthetic methionine activity in the supplementation of soybean meal. Since the amino acid patterns of soybean meal and fish meal are quite similar with the exception of the methionine levels, it is both theoretically and practically possible to replace fish meal in a broiler diet with methionine and soybean meal. We have just completed an extensive broiler floor pen trial that demonstrates this point quite conclusively. A corn-soybean meal ration was formulated to contain 1100 calories of productive energy per pound of feed so that energy would not limit the full utilization of the protein in the diet. The results obtained are given on Table 4. These data illustrate several points that I have outlined here. In the first place they demonstrate that a corn-soybean meal diet, properly supplemented with known vitamins, minerals and amino acids will support growth at least equivalent to that obtained with diets containing fish meal. Thus, the nutritional value of fish meal can be fully accounted for by its content of known nutrients. When 5 % fish meal was replaced by the calculated equivalent quantity of nutrients contributed by corn, soybean meal fat and dicalcium phosphate, the performance of the birds was significantly poorer. Our calculations indicated an additional need for methionine which was supplied by .043 % MHA. This addition did improve the performance significantly but it was still less than that obtained with fish meal. A further

TABLE IV

| Diet                     | 56 day results |      |
|--------------------------|----------------|------|
|                          | Gain (gm)      | F/G  |
| Corn-soybean meal (CS)   | 1503           | 1.86 |
| CS + .043 % MHA          | 1533           | 1.85 |
| CS + .24 % MHA           | 1594           | 1.77 |
| CS + .12 % MHA           | 1591           | 1.81 |
| Corn-soy-fish meal (CSF) | 1561           | 1.83 |
| CSF + .20 % MHA          | 1601           | 1.80 |

Diets contained 23 % protein and 110 calories/lb (P. E.) Fishmeal level was 5 %.

addition of MHA to a level of 0.12 % resulted in better performance than was obtained on the fish meal diet. This would indicate that 5 % fish meal did not supply sufficient methionine for maximum growth. The fact that the addition of 0.20 % MHA to the diet containing 5 % fish meal improved the bird performance demonstrates conclusively that this is true.

These results also point up another important fact to remember in determining the levels of amino acids that should be used in practical broiler rations. This is that as the level of a supplementary amino acid is increased the unit response as measured by weight gain or feed conversion decreases as one approaches the absolute biological requirement of the bird for that amino acid. The biological optimum is always greater than the economic optimum because of the shape of this typical dose-response curve. The determination of the economic optimum must take into consideration not only the relative costs of synthetic vs natural amino acid but also the economics of least-cost vs least-time rations.

In this specific feeding trial the calculated biological requirement for supplemented MHA was 0.24 % of the diet while the economic optimum was about 0.1 %. Since the second limiting amino acid in a corn-soybean meal ration is glycine, supplementation with glycine should extend the range of supplementation with methionine. This has been demonstrated to be the case and a recent study from our laboratory illustrates this point. The results are given on Table 5. In the absence of glycine 0.46 % MHA did not improve performance over that obtained at 0.19 % MHA with a very low level of glycine. When the level of glycine was increased, however, a significant improvement in performance was obtained at the higher MHA level. A further improvement resulted from the addition of the next two limiting amino acids, lysine and arginine.

TABLE V

| Diet                                                  | 28 day results |      |
|-------------------------------------------------------|----------------|------|
|                                                       | Gain (gm)      | F/G  |
| Corn-soybean meal (CS)                                | 426            | 1.82 |
| CS + .19 % MHA + .05 % Gly                            | 437            | 1.74 |
| CS + .46 % MHA                                        | 437            | 1.68 |
| CS + .46 % MHA + .34 % Gly                            | 452            | 1.68 |
| CS + .46 % MHA + .34 % Gly<br>+ .19 % Lys + .32 % Arg | 466            | 1.59 |

Diets contained 20 % protein and 1000 calories/lb (P. E.)

Studies of this type are important because they tell us the order of amino acid limitations in mixtures of practical feed ingredients. How many synthetic amino acids and how much of each should be used in commercial practice will depend on the specific economics involved. The important point is that the biology has been demonstrated so that we know what we can do with



## TOTAL SULFUR REQUIREMENT OF THE CHICK

|                                                 |
|-------------------------------------------------|
| <b>SO<sub>4</sub> Methionine<br/>or Cystine</b> |
| <b>Methionine<br/>or<br/>Cystine</b>            |
| <b>Methionine</b>                               |

AMINO ACID IN PROTEIN, PER CENT

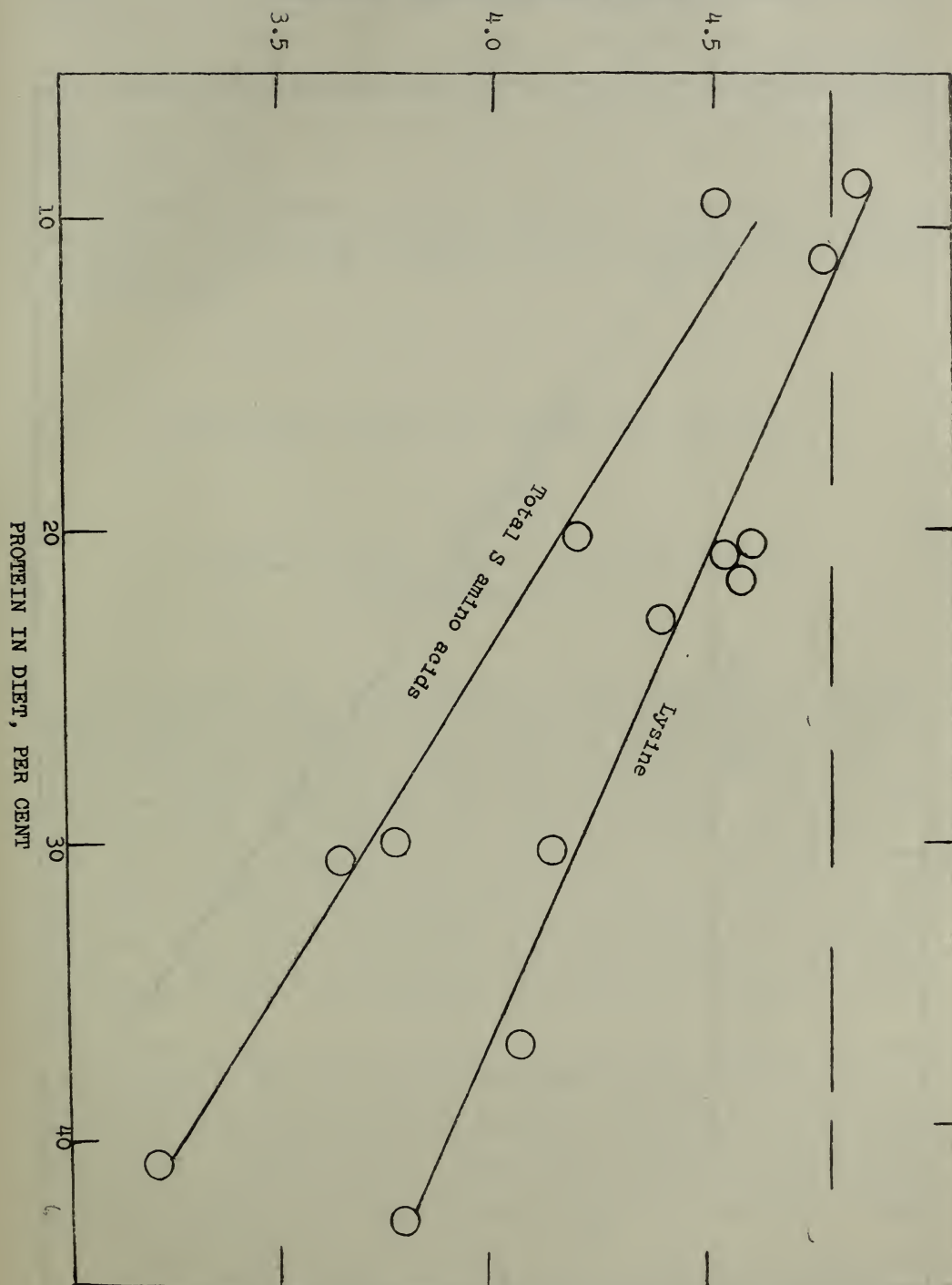


Figure 2



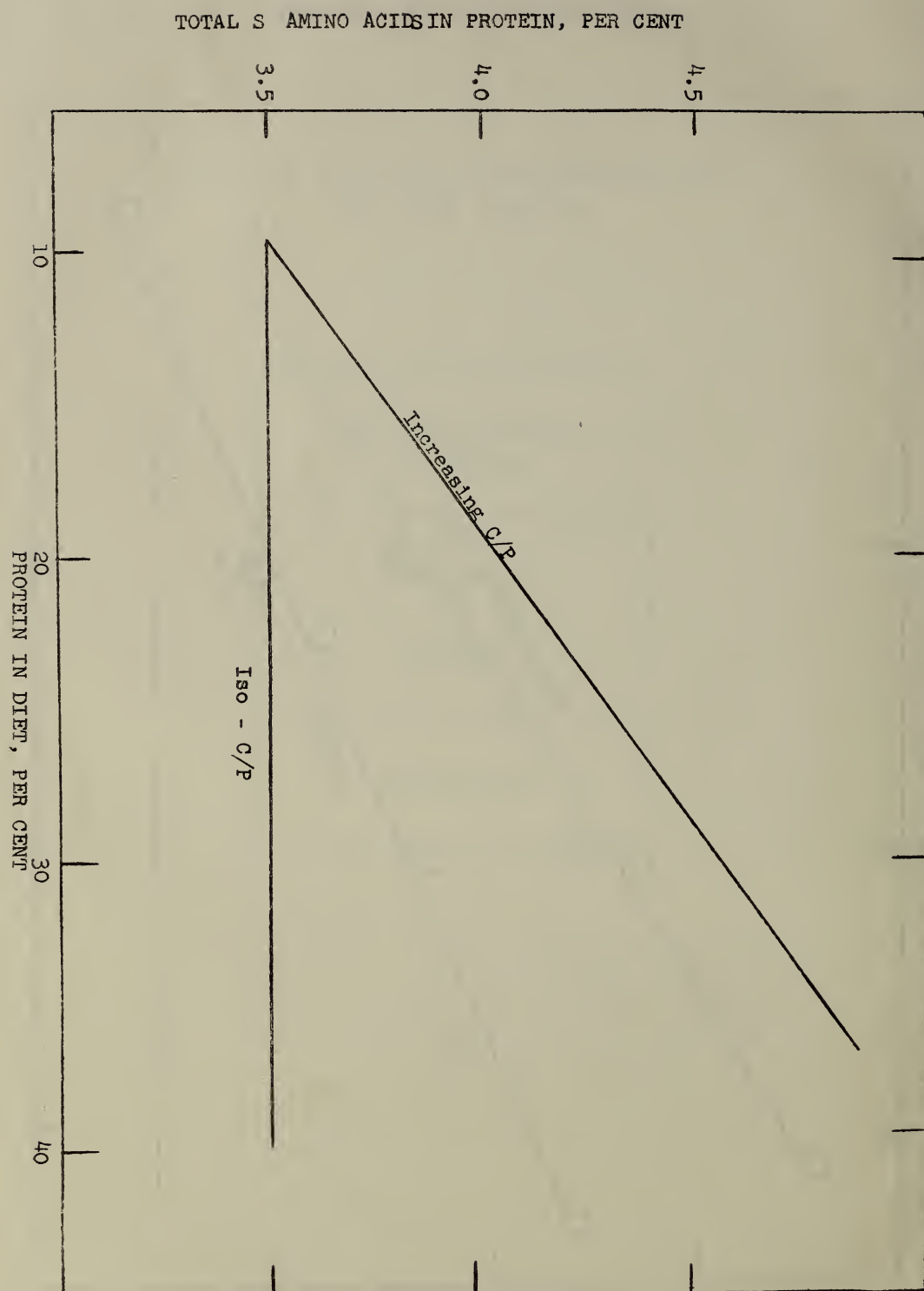


Figure 3

synthetic amino acids and as research in this field advances, the practical applications will become more closely related to the theoretical.

Because the broiler is such a satisfactory laboratory animal, most amino acid studies have been conducted with broilers. The principles demonstrated with the broiler apply however to all types of poultry and specific investigations are now underway in many laboratories to define the amino acid needs of laying hens, turkeys and other poultry under all types of feeding and production conditions.

Although many problems remain to be solved, the information now available on amino acid requirements of poultry will permit a more efficient utilization of proteins in feeds which in turn will result in cheaper and more efficient production costs.

## PROTEINS: FACTORS AFFECTING QUALITY

C. R. GRAU

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It is fortunate that several speakers in this symposium are discussing protein nutrition, because a topic so complex surely deserves consideration from several points of view. Even today, the protein problem cannot be reduced entirely to terms of individual amino acids, and yet it has for some time, been clearly unsatisfactory to consider «quality» as some single measurable value. To bridge this gap—between knowing what answers we seek and not yet knowing how to find them—we have had to make numerous assumptions about amino acids in protein combinations. It has been useful to assume, for example, that the amount of an amino acid contained in a protein, as determined by chemical analysis, is a satisfactory measure of the amount of that amino acid which is available to the animal. As research continues, this assumption will gradually be obviated by accurate data.

In order to make estimates of what is loosely called quality of a protein food, we need to know how much of each amino acid the food supplies in a form utilizable by the species and age of animal with which we are concerned. In the past, many methods have been devised for estimating the over-all quality of a protein by feeding tests (1). These tests have played an important role in the development of nutritional science, but they will be of little use in future research, because they are based on the untenable assumption that a single estimate can be made of the sum of all amino acids.

In protein quality studies, the amino acids are naturally of primary importance, but we must also consider certain special values of the protein portion of the food. (These special values may be derived from particular



peptide combinations which are utilized directly for protein synthesis, or they may be obtained from compounds containing amino acids which act in some specific way in the body, for example, as hormones, or as especially active amino acid donors. At the present time, there is little direct evidence of such special effects, but they may well exist, and this possibility should not be overlooked.)

## I. ACCEPTABILITY

Because we are considering protein foods, not the simpler matter of pure proteins isolated from foods, we must also consider certain non-protein components that may affect protein utilization.

The amounts of food ingested may be decreased by such physical factors as a tendency for the foodstuff to stick in the mouth (as some raw legume meals do, for example) or by repugnant odors, colors, or textures. In this respect, differences among ages and species are quite marked, ranging from the nearly total lack of discrimination of newly hatched chicks to the marked finickiness of dairy cows.

## II. METABOLIZABILITY OF AMINO ACIDS

This complex topic includes the factors most interesting to us.

A. *Digestibility.* The first part of the release of food amino acids can be measured grossly by relating fecal nitrogen to ingested nitrogen. However, there is mounting evidence that pancreatic and intestinal secretions may contribute significantly to the nitrogen content of the feces, especially when raw soybeans are fed (2). That part of a protein which is not digestible is obviously useless to the animal, but attempts to relate digestibility *in vitro* to food value have failed, because digestion is only one of a chain of factors that determine qualities.

B. *Availability.* This is an especially useful term when we are considering differences among proteins in what may be thought of as the partial digestibility of their component amino acids. When we can accurately estimate the availability of each of the amino acids in a protein food, we shall be able to formulate diets truly effectively. In lieu of such complete information, the availabilities of two or three key amino acids, together with an estimate of nitrogen digestibility, may prove to be a useful index for estimating the value of a protein source.

Several attempts have been made to estimate availabilities biologically (3). None of these is completely satisfactory, but eventually some good methods will undoubtedly be devised. Chemical methods pose more difficult problems, but a good start in this direction has been made by Carpenter and his co-workers, who estimate lysine availability from the number of free amino groups that will react with dinitrofluorobenzene (4).

C. *Amino Acid Balance.* That an excess of one amino acid in the diet may affect the need for another amino acid is now well established. The extremely complex interrelations which may occur have not yet been fitted into a generalized theory, although good progress has been made in this field by

Harper (5) and others. Indisputably, the mechanisms of imbalance must be understood to permit accurate prediction of the results of feeding new combinations of proteins.

D. *Time Factors.* For best protein use, it is necessary not only that there be a balanced supply of amino acids present in each day's ration, but also that all amino acids be ingested at about the same time (6). Much remains to be learned of how amino acid utilization is affected by differential release of amino acids from proteins as food passes through the alimentary canal.

### III. HARMFUL COMPONENTS IN PROTEIN FOODS

The list of substances known to be harmful continues to grow, and simultaneously new means of inactivating or removing them are being developed (7). Natural materials contain such diverse inhibitors as the pigment gossypol of cottonseed (8), antitrypsin and other heat-labile substances of the soybean (9), and the antipyridoxine, growth-depressant of the linseed (10).

We come now to a discussion of the variables which influence the qualities of protein foods. The materials which provide amino acids are mostly by-products, or secondary products of human food manufacture, and are generally less important economically than the associated human food component.

The *first* and greatest variable in quality of proteins is inherent in the material itself. Different vegetable proteins, for example, differ markedly in amino acid content. Furthermore, these differences are often exaggerated by subsequent treatment.

The *second* factor is storage prior to processing. The amino acid losses attributable to storage conditions are extremely variable, ranging from very slight losses in grains stored for several years to very great losses in some fish subjected to microbial spoilage. It has been found that even quite extensive spoilage does not necessarily greatly decrease nutritive value; however, if spoilage in any way affects protein quality, it is most likely to be adversely.

The *third* major factor in quality changes is heating during processing. Although carefully controlled heating is beneficial to certain protein foods, primarily because it inactivates harmful components, scorching is definitely harmful to all. For every foodstuff, the optimum processing procedure must be established to ensure maximum yield of products (such as oils), to guarantee maximum protein qualities, and to reduce to a minimum the harmful components. Liener (8) has summarized these processing problems for vegetable protein foods.

Heat damage may be caused by a number of different reactions, depending on conditions of oxygen supply, moisture, temperature, time, and catalysts present. Most important among these reactions is that causing «browning», essentially the binding of free amino groups of proteins by carbonyl groups of carbohydrates, in such a way that brown colors are produced, and amino groups inactivated or destroyed (9). Lysine is especially vulnerable to this type damage, but other amino acids may also be affected (4).

*Fourth*, damage to protein foods may occur during storage after processing (11). Most of this sort of damage is indirectly related to proteins: fats are usually the components that are undergoing deterioration by oxidative rancidity and polymerization.



## SUMMARY

Quality of proteins must eventually be related to amounts of available individual amino acids, estimated biologically and measured by chemical tests. With the development of such tests, it will become possible to improve animal nutrition by so controlling processing and storage methods that amino acid values will be maximized and harmful components minimized.

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## DISCUSSION

*Dr. Kohn* (Scotland). Both Dr. Maddy and Dr. Grau have stated that poultry can absorb amino acids into their blood stream. I would appreciate a bibliographic reference on this subject, as in recent work with rats, using proteins, we have not been able to observe other amino acid detections other than the ones mentioned.

*Dr. Maddy* (U. S.). I cannot give you an exact bibliographic reference right now but I can say that several works have been published on this subject, indicating that amino acids and dry peptides are more largely absorbed than the individual ones.

*Dr. Kohn*. Does this apply to poultry or to other animal species?

*Dr. Maddy* (U. S.). Research was conducted on rats and human beings. Now we are conducting some tests on this subject, although nothing has been published as yet.

*Dr. Kohn* (Scotland). I would appreciate any references you may be able to supply.

*Dr. Grau* (U. S.). Just one comment, please. What I have said was not as definite as the explanations supplied by *Dr. Maddy*, because I did not have any exact knowledge about those tests which indicate that any combination of amino acids has given worse results than proteins. However, there might be peptides or other natural food components acting as individual separate amino acid sources. I think we should try and find out whether this is important or not.

*Dr. Maddy* (U. S.). I would like to make it clear that I do not believe in any function of protein procedure per se. I believe that amino acids may be fully used, same as proteins.

*Dr. Grau* (U. S.). I agree to that. I think it is a subject that deserves further research.

*Dr. Kohn*. With regard to soybean and fish meals has *Dr. Maddy* studied the analysis of carcass according to the food administered, in order to modify carcass quality in poultry?

*Dr. Maddy* (U. S.). In our study we did not establish any analysis of carcass. We conducted a good number of tests on these years ago, and we became convinced that carcass composition of poultry can be modified by changing the calory-protein ratio. When you asked this question, did you believe there was any reason for any difference in carcass composition?

*Dr. Kohn* (Scotland). No, sir, I did not. I agree with you and with *Dr. Grau* that the most useful criteria we have at present is weight increase for feed utilization efficiency.

*Dr. Clausen* (Denmark). Another remark regarding carcass quality. In almost all our tests we obtain different results with sows and with castrated males, according to the balance between the different amino acids.

MODERATOR. If there are no more questions we will proceed to the last papers of this Panel, on the subject of «Nutritional Stress Caused by Fat Addition into the Feeds», by *Dr. Varela* (Spain).

## ✓ NUTRITIONAL STRESS CAUSED BY FAT ADDITION INTO THE FEEDS ✕

BY

DR. G. VARELA

«El Zaidin», Granada. Spain

The problem of adapting the animal's physiology to a nutrient has brought about a lot of scientific literature and has led to the modern concept of the ratio animal-feed as a basic subject in the present stage of animal nutrition.

In fat digestion as well as in other immediate principles (nutrients) the determination of the index of digestibility is a problem of estimation of quantity in the whole process (in toto).

*Drs. García de la Puerta, López Grande, Morata, Boza and myself* have



observed that there was a specific action in each fat addition since the diet in the animal fed for instance with olive oil has a different index of digestibility (lower) for butter when this fat was suddenly changed in the ration; this index being lower than the usual one for an animal used to butter.

In human nutrition this phenomenon is shown with the same characteristics when a food fat is suddenly replaced by another one the index of digestibility being lower than when this fat has been usually fed.

All this leads us to the idea of selective adaptation to digestive processus that is to say that a given fat will interrupt a firmer physiologism of fat digestion, being necessary a re-adaptation as the new concept of digestive stress reads but before we get that idea we can check a reduction of digestibility that we measure by digestibility index. We think that the above justify the fact of carrying out these tests whose development is as follows: we carried out this work with rats in different physiological status (at the weaning or early age). These animals are fed with a maintenance standard diet with different fat levels. The rats fed either with olive oil or butter as the only fat source diet for a month time (period that we think sufficient for adaptation to a given fat) were submitted to a sudden change in the fat ingredient, feeding vegetable fat to those which were being fed with animal fat and vice-versa. Mitchel's technique was used to determine the digestibility index for the new fat in various periods of time, in order to observe how this adaptation to the fat was taking place.

The two first tests were intended to check the reduction of the digestibility index before a sudden change of the fat through varying alternatively the type of protein used (standard type with powder milk or pure casein) as well as the amount of fat in the diet.

It is well known that all physio-chemical processus which produce a fat emulsion in the intake, play a very important role in fat digestibility. For this reason, many workers are carrying out many research experiences to find out a procedure to increase fat digestibility through the addition of non-toxic emulsifying agents. We think that the effect of these emulsifying agents should be precisely studied with rats which have undergone a reduction of digestibility for a given fat as a result of a sudden change of the same in the diet as we did in our two first experiences.

For this reason, we studied in the third part of our tests the action from the digestive stress point of view of two emulsifiers of well-known efficacy (Tween 40 and Dioctyl Sulfosuccinate) on five sets of rats of different physiological state.

The setting up of this working hypothesis is intended to find out if for a given fat and a given physiological state the emulsifier prevents digestibility from going down and in which cases this action is more effective. We also tried to know if there is any influence of the physiological state of the animal upon the additive's action for a determined fat and emulsifier and also the variations which may occur as a result of the fat used (animal or vegetable).

TABLE OF THE VARIATIONS OF THE DIGESTIBILITY INDEX IN THE 3 TESTS

DIFFERENCES CONTROLLED THROUGH DIGESTIBILITY INDEX

| Observ. | 0 — 1 | 0 — 2 | 0 — 3 | Experimental<br>Error | Lower<br>significant<br>difference |
|---------|-------|-------|-------|-----------------------|------------------------------------|
| (1)     | —7.1  | —17.6 | —59.5 | 3.33                  | 3.437                              |
| (2)     | —6.5  | —12.1 | —89.2 | 6.23                  | 4.922                              |
| (3)     | —7.7  | —32.3 | —71.5 | 4.06                  | 3.787                              |
| (4)     | —7.1  | — 9.5 | —16.8 | 3.27                  | 3.392                              |
| (5)     | —1.9  | + 2.7 | + 3.8 | 0.33                  | 1.923                              |
| (6)     | —3.9  | + 5.6 | — 5.3 | 1.46                  | 2.495                              |
| (7)     | —10.0 | — 3.3 | + 7.3 | 1.39                  | 2.455                              |

(1) — Without emulsifier and with 15 % of fat (olive oil and butter).

(2) — Without emulsifier and with 20 % butter.

(3) — Without emulsifier and with 20 % olive oil.

(4) — With Tween — 40 and 20 % olive oil.

(5) — With Tween — 40 and 20 % butter.

(6) — With Tween — 40 % and 20 % olive oil and butter.

We know that the fat content of the diet has an effect upon the volume of the intake since fat is an important agent of palatability. For this reason, we try in our tests to disclose in which way fat concentration in the ration had an influence upon its palatability.

Digested fat has a repercussion on weight increase. For this reason we have thought it interesting to determine the index of growth efficiency and to reply this increase in life weight with the amount of fat daily digested.

All the results are submitted to a statistical analysis in order to know their significance.

The rats of the two first tests (the ones without emulsifier) were grouped as follows: in one side all those which were used to olive oil and in the other the ones which were adapted to butter. In both groups of nine rats each, we have figured out an arithmetic media of the index of growth efficiency before changing the fat in the diet (that we consider as control) and another one for the index of growth efficiency after the change of the fat. In the Table in can be noticed that on changing the type of fat there is a significant reduction of the same that we have to relate to digestive stress and not to hazard. The significance of this fact is of 0.01 % of probability for the olive oil and of 0.05 % for butter.

In the set of the third experience where emulsifiers were used the difference formerly met did not have any significance and, therefore, the emulsifier overcomes the effect of the stress upon the index of growth efficiency. The probability of this fact being true gives us data to disclose the fact that there is no significance between the values of T for differences between the indexes before and after the change in animals with and without emulsifiers.



## CONCLUSIONS

1) The stress factor appears due to a sudden change in the fat usually included in the diet.

2) This digestive stress to fat is at the beginning slow and at the end of twelve or fifteen days it becomes more intense.

3) This phenomenon is brought about equally in rats adapted to butter when we change this fat in the diet into olive oil and in rats used to olive oil when we start feeding them with butter; that is to say that animals are not «specific» for one fat or the other.

4) This stress shows a significant reduction of the index of digestibility of fat.

5) Through the action of the emulsifiers this reduction of fat digestibility disappears. It means that these agents have a protection effect against stress.

6) In the case of olive oil and Tween-40, the physiological state of the animals has not got any influence on the emulsifier action, regardless whether we take animals at weaning time or at a very early age.

7) In the case of butter and Tween-40, a higher significance of the interaction physiological state-change of the digestibility index is noticed, the emulsifier being more effective and faster response in the weaned rats rather than in the adults.

8) Comparing the two tested fats between them under the action of Tween-40, we find that each fat behaves individually in the same manner compared with the value changes of the digestibility index through the test.

9) The maximum of efficacy of the Tween-40 upon the index of digestibility at the twelve or fifteen days after having changed the fat suddenly: This is observed a little later due to the low dosis of emulsifier utilized.

10) A higher efficacy of Tween-40 versus dioctyl sulfocinate is observed.

11) It is clearly noticed a reduction of the growth index due to the sudden presence in the intake of strange food fat with a 99 % of probability.

12) The reduction of the index of growth efficacy disappears due to the action of the emulsifiers.

13) There is a relation between digested fat and fat value at the fat level used and as a result of the digestive stress this relation goes down to a 70 %.

14) For the action of the emulsifiers the former relation is increased up to a 90 %; that is to say, there is a significant action upon 5 % of the amulsifiers on palatability due to a fat stress.

## DISCUSSION

*Dr. Clausen* (Denmark). I did not understand the question on dosages and fat for pig weaning. We have performed some tests on carcass improvement with skimmed milk, and have not found any differences between feed conversion, weight increase and carcass quality.

*Dr. Varela* (Spain). What I really wanted to say is that Dr. Galán here

has been able to observe in his work an improved performance at weaning when feeding lactose previously to the piglets.

*Dr. Peruchon de Brochard* (France). I have followed your report with the greatest interest. My congratulations, sir. Could you please furnish some details about the percentage of TWEEN incorporated to your formula?

*Dr. Varela* (Spain). We have used TWEEN because we lacked *Diocetyl Sulfosuccinate*. We use it at the rate of one miligram per gram of fat. We mix the fat to the emulgent agent using an electric mixer.



INTRODUCTORY REMARKS FOR PANEL V — PROCESSING AND  
QUALITY — AT THE INTERNATIONAL ANIMAL FEED SYM-  
POSIUM, MADRID. OCTOBER 20TH, 1960

This is a scientific symposium and the level of the papers presented has been very high, but, in introducing the panel on «Processing and Quality», I would like to emphasize the word «processing» as an excuse for striking a rather practical note. I propose to refer to the means by which the processor may contribute to the quality demanded in animal feeding stuffs.

Firstly, I want to make an assumption in a not very well explored area which is, however, receiving attention, to my knowledge, in the United States and in the United Kingdom at any rate. This is the assumption that, with the exception of a few special ingredients (in particular vitamins and possibly antibiotics), the effect of the processes used to make the raw materials into finished formula feeds, or compound animal feeding stuffs, is only marginal. This is not to say by any means that the processing of raw materials *before* they arrive at a compound animal feeding stuffs factory does not have a very marked effect on their performance and the quality of the final feed. We are in fact about to hear two important papers dealing with the effects of processing on proteins in the major raw material protein sources — animal, fish and vegetable. But, referring only to the normal processes used in feed manufacture, and making the assumption that they have only a small effect on quality, it follows that the ability of the animal feeding stuffs manufacturer to reproduce the quality which is theoretically obtainable — as a result of the sort of research which has culminated in this symposium — depends on his ability to accurately combine the various ingredients available to him so that they will present the designed feed formula to the animal or bird.

Secondly, the animal feed industry is largely a supplier to industry itself — the farming industry — and the assessment of quality which will be applied to its products will be an economic one measured eventually in terms of the

cost per dozen eggs, per pound of meat or per gallon of milk, and this aspect will be dealt with in our second two papers on «Least-Cost Feed Formulation». Quality must therefore mean economic quality.

We are also to have a paper on «Feed Additives», ingredients which may be added in levels ranging from 1 % or 2 % down to only parts per million, and they may bring up the number of ingredients added to each formula to as many as 20 or 30.

Now, because the need for the ingredients being present in the finished product according to the formula is, I suggest, more important to quality than the way in which they are normally treated in an animal feeding stuffs plant, I would like to emphasize how much quality depends upon two key processes. These processes are firstly proportioning, which includes selecting the right ingredients and weighing out the correct amounts, and secondly mixing.

We may obtain some idea of what level of quality can be achieved in the proportioning process by considering what the real sources of error are, and these are broadly:

- (1) variation in the analysis of raw materials;
- (2) errors in weighing; and
- (3) omissions of some of the ingredients or accidental substitution by another ingredient.

A recent study in the U. K. has indicated that likely errors in weighing are sufficiently over-shadowed by the variations in raw materials commonly available in that country to rule them out as a major source of error, provided mechanical feeders are used. (It has not proved possible to gain a true estimate of probable error when using hand-operated slides. Spot checks show that at the worst this may be serious.)

It was assumed that there could be an error of 10 lbs. in every weighment within a 5-ton batch, and this has been shown to be easily achievable in practice. From this a standard deviation in the protein content of six standard formulae was calculated.

Variations due to differences in analysis of raw materials were calculated from experience of spot samples of all materials taken over a period of a year. The standard deviation in protein content due to weighing errors was of the order of 0.05 %. That due to variations in raw materials was 0.5 %.

Control of the right selection of ingredients to avoid any omissions may be built into the plant by using punched cards. The same punched cards may be used to ensure the proper routing of the blended materials to the production and the packing units. It is a matter of opinion, however, whether the responsibility for this particular check would not better be given to management supervision, because there is still the ultimate source of error in that the blending bins themselves have to be fed with the correct materials, and no amount of automation, after an error at this point, can correct such an error.

The picture may be a little different when considering trace ingredients, vitamins, drugs, minerals and so on. Generally they are not subject to so much variation in quality; they are required in small quantities; they are expensive; and they are each quite vital to the performance of a feed, hence the most elaborate type of plant may be justified for their inclusion.

The conclusion arrived at was that, in the U. K. at any rate, suitably



designed plant can virtually remove chances of error in the addition of feed additives for any reason other than gross negligence, but that protein content can vary uncontrollably with one standard deviation of as much as 5 %.

The next problem related to quality is mixing, and the efficiency of the mixing operation is not a particularly easy one to measure. However, some indication of the route towards optimum quality may be gained by considering what happens in the mixing operation. It may be convenient to regard mixing in two senses:

- (1) local mixing, which can be expressed in terms of a deviation of one small sample from another taken quite close to it in a mixer; and
- (2) coarse mixing, which can be expressed in terms of the deviation of one small sample from another taken from a distant point of a mixer.

This permits the concept of homogeneity as having been achieved when the deviation between the samples taken far apart is no greater than the deviation between samples taken close together.

Most mixers designed with adequate internal mechanical transport are capable of approaching homogeneity in this sense, but this still leaves us with the problem of saying what is an adequate standard of local mixing. There is no doubt that a certain lack of homogeneity is easily catered for by storage of vitamins and nutrients in the body of an animal or bird, and in our present state of knowledge we can say little more than that young animals with a small daily intake of food probably need a more finely mixed ration than, say, adult cattle.

A limited series of tests have suggested that homogeneity cannot be quite reached in practice. It seems that, when the mixing operation starts, local variations are reduced first and the ratio of the gross variations to local variations is high, being of the order of 5 to 15. This reduces in about 3/15 minutes, depending on the type of mixer, to a fairly stable figure of about 1.3, and after this happens both the local and coarse variations reduce together. Finally, a degree of local mixing is reached which is probably determined by the nature of the ingredients in the mixture.

The relative size and shape of particles to be mixed is of great importance. Severe regressions in mixing efficiency have been found in mixtures which show a marked disparity in size and shape, such as would occur in mixing corn and fine-ground soya meal, for example. The range of densities with which we are concerned, however, does not seem to be very significant.

The question of mixing trace ingredients has received a considerable amount of attention. Two methods are advocated. Either the ingredients are mixed dry, or they are mixed as suspensions or solutions in liquids. Adding trace ingredients in liquid form has some undoubted advantages. Metering is easy, contamination can be avoided and there are some good high-speed liquid mixers, and, by pumping them in at the last stage of manufacture, losses are avoided. The limit to which the process can be used is provided by the amount of moisture which can be added to a feed. Dry mixing can, however, be done satisfactorily and seems to have found favour in a number of countries, highest efficiencies being gained when the powdered additives are added slowly to a mixer. I am not aware of any published work on the relative mixing efficiencies of these two methods.

I have spoken of the key processes which may cause limitation in quality of animal feeds. The subject is, however, but superficially explored. It will not be until we know a great deal more about the tolerance of animals and birds to variation in the components of the feeds which are so carefully designed for them that very much more progress can be made towards determining what is the optimum economic quality obtainable.



## PANEL V

MODERATOR: *Dr. Van Snick* (Belgium).

MODERATOR. Gentlemen: We are going to initiate the study and discussion of the different reports that will be introduced at this session. I call your attention to the papers submitted by Messrs. Simpson, Collinwood and Nogues, which will deal mostly, with feed manufacturing. After these subjects have been properly discussed we will proceed with other reports on marketing of animal feeds. First of all I would like to emphasize the important role played by the animal feed industry, as there is no doubt that the development of this important area has made a great contribution to the improvement and development of animal production, and will continue to play a similarly important role in the future. Now, Dr. Simpson will proceed with his paper.

## NEW CONCEPTS IN FEED PROCESSING

BY

DR. JACKSON E. SIMPSON

Assistant to Deputy Administrator Agricultural Research Service  
U. S. Department of Agriculture

## ABSTRACT

The need for processed feeds is pointed out. How the USDA, through its Utilization Research and Development Program, seeks to find new uses for agricultural commodities is outlined. The research conducted by the four Utilization Research and Development Divisions to develop new feed products and processes is reviewed.

## NEED FOR PROCESSED FEEDS

Economical production of animal products depends upon efficient utilization of the feed by the animal and upon supplying these nutrient elements at the lowest cost. These needs are being increasingly met by processed feeds, since processing offers these potential advantages: (a) better preservation of the natural nutrients in the feed materials; (b) «tailor made» feed formulations to fit specific needs; (c) incorporation of any desired feed supplements; (d) improved appearance and palatability of feeds; (e) opportunity to remove or nullify any deleterious components; (f) easier and cheaper handling, storage and shipping; (g) wider geographic distribution of feeds.

Processing also offers advantages to the grower of the feeds: (a) feed-stuffs can be produced having optimum feeding value, thus assuring good prices; and (b) feeds can be marketed in a more orderly way with greater overall returns.

U. S. production of by-product feed — i. e., processed feed ingredients — is steadily increasing. Currently, oilseed cake and meal accounts for nearly half of these byproduct feeds; wheat mill-feeds about one-fifth; and alfalfa meal, tankage and meat meal, and grain gluten about one-seventh.

The potential advantages of feed processing to the grower of feeds and to the producer of the animal products can best be realized through vigorous and continuing research efforts. Much progress has been made to improve feed processing and feed products, but these problems are never static. As feeding practices change, feed processing research must go forward to meet new needs. And conversely, new findings in feed processing and products affect feeding practices.

The purpose of this discussion is to review the principal research conducted in the U. S. Department of Agriculture's Utilization Research and Development program to develop better feed processes and products. This discussion is primarily an orientation in these principal research areas. Detailed information on research methodology and research finding will be gladly supplied by the particular Utilization Research and Development laboratory. There may be opportunity during this symposium to answer many of the questions.

## WHAT IS USDA UTILIZATION RESEARCH?

Utilization research, as applied to agriculture, is an organized effort through science and technology to increase present uses for farm products and to discover and develop varied new uses for them. The U. S. Department of Agriculture has been interested in this sort of research ever since the Department's establishment nearly a hundred years ago. This part of the Department's program was given particular impetus with the establishment of four regional utilization research and development laboratories about 1940. In these laboratories ways are sought for imparting new chemical and physical characteristics that make good products still better. Also, entirely new products are being created, through chemistry and other sciences, to meet needs not now



satisfied by products from any other sources. Such new and broadened uses for agricultural crops help the farmer by giving him more returns and less surpluses. These new and better products give the consumer things he needs and assure higher living standards for all.

USDA efforts to find new outlets for farm commodities go across the entire horizon of agricultural interests — foods, feeds, and industrial products. Feed research has been a vital part of this program.

A major portion of the Department's utilization research is conducted in four regional laboratories and a number of associated field stations. These regional laboratories are of similar design, and have the most modern scientific and engineering equipment. Each does basic and applied research in the fields of chemistry, physics, engineering, and related sciences. Process and product development includes pilot plant investigations, with many of the studies extended to evaluations in commercial plants.

Cooperative work — some under contract — is undertaken with State Experiment Stations, colleges and universities, and various industrial organizations. Ideas are exchanged with all segments of agricultural interests — producers, manufacturers, storage and distribution groups, and ultimate consumers.

Recently a foreign program of utilization research has been established largely supported by funds generated under the P. L. 480 program. This research program was initiated in Europa and the Near East, and plans are for extending it to other countries including those in South America and the Middle and Far East.

## USDA UTILIZATION RESEARCH ON FEED PROCESSES AND PRODUCTS

### A. *Western Utilization Research and Development Division*

Research has been done at the Western Utilization Research and Development Division to isolate and identify components of forages that have specific growth promoting properties. This kind of knowledge is important to the development of more efficient feeds. Recently, cooperative studies by Department and State Experiment Station scientists have resulted in the isolation of a growth-promoting constituent from ladine clover. This substance has been shown to be an estrogen (female sex hormone) that occurs in varying amounts in all principal legume forages grown in the United States. This newly discovered chemical, named «coumestrol,» has benefits in improving growth feed efficiency and increasing milk production, but under certain conditions may have some detrimental effects such as breeding difficulties in cattle and sheep. It is hoped that continued research will point the way to take full advantage of the desired properties of coumestrol and to overcome any detrimental characteristics.

Fundamental studies of the chemical composition of alfalfa and other forages, coupled with cooperative feeding experiments, have shown that the saponin content contributes to bloat in ruminants and retards growth of poultry. The saponin fraction has been shown to be a complex mixture of several saponins, with specific occurrence and physiological effects yet to be

established. Techniques are being sought either to remove these harmful saponins or to nullify their effects. Development of new analytical methods for isolating and identifying these saponins also are aiding plant geneticists to develop varieties having little or no undesired saponins.

Research is in progress to explore ways of upgrading cereal grains and products derived from them for use in feeds. The objective is to obtain their maximum feed value in high energy growth rations, particularly for chicks, and to discover the mechanisms by which such improvements are achieved. Treatment of cereal grain products with water followed by drying has shown considerable promise. Addition of enzymes also is being studied. Principal work in this area has been on wheats and barleys.

In the United States, dehydrated forages, particularly alfalfa meal, are used as vitamin-rich supplements in mixed feeds — sources of provitamin A (beta carotene), xanthophyll, and vitamin E. USDA feed research seeks to find ways to maintain and enhance the good properties of these dehydrated forages and to overcome their deficiencies.

One of the serious deficiencies of dehydrated forages is the loss of valuable nutrients due to natural oxidation during storage. The Western Division has spear-headed an extensive research program to find means of overcoming this oxidative degeneration. Evaluation of several hundred chemical compounds revealed that certain quinoline derivatives were the most effective stabilizers. One of these, an ethoxyquin known as 1,2-dihydro-6-ethoxy-2,2,4-trimethyl quinoline was found to be most suitable. Extensive pharmacological and other evaluations were made to determine its possible physiological effects on animals and poultry fed such treated feeds. These evaluations — typical of the care in proving the suitability of U. S. food and feed treatments — involved acute and chronic toxicity studies and exhaustive chemical determinations. Such techniques as use of radioactive tracers were employed to determine the fate of the chemical in metabolism. Many industrial-scale applications were evaluated. The use of 1,2-dihydro-6-ethoxy-2,2,4-trimethyl-quinoline is now approved (in 1949) by the U. S. Food and Drug Administration for dehydrated forage crops and poultry feeds in amounts not exceeding 150 parts per million in the finished feeds.

Applied at rate of about one-half pound per ton and at cost of not over \$1.00, about three-fourths of the labile nutrients are retained over a storage period of six months as compared to a one-fourth retention for untreated forage stored under the same conditions.

The feed industry has widely acclaimed this research, and the use of this method of reducing nutrient losses in dehydrated forages has been almost universally adopted by the U. S. industry.

The work on antioxidants for dehydrated forage meals lead indirectly to other improvements in processed feeds. Early in the antioxidant work it became apparent that some vehicle for distributing the antioxidant was very desirable to assure uniform treatment. Since a large number of the antioxidants studied were oil-soluble, various vegetable oils and animal fats were tried. A number were successfully used for applying the chemical stabilizers under investigation. It was found that the use of such fats and oils had other advantages: gave the feeds a rich, uniform color that was stable, and reduced the dustiness of the feeds which is a serious problem in feed manufacturing plants and in handling and feeding practices.



*B. Eastern Utilization Research and Development Division*

One of the responsibilities of the Eastern Division is to develop new uses for animal products. An important problem in this area is to find new outlets for animal fats. During the past decade important changes have taken place in the production and utilization of animal fats, especially inedible tallows and greases. From 1947 to 1959 U. S. tallow and grease production has increased about 65 % — from 2.0 billion pounds to 3.3 billion pounds. In the mid-forties two-thirds (1.5 billion pounds) was used to make soaps, but this market has steadily declined — due to the inroads of synthetic detergents — so that today less than one-fourth (about 700 million pounds) goes into this use.

Pioneering research by the American Meat Institute Foundation has shown that edible grade animal fats, from a nutritional standpoint, could be utilized advantageously in animal feeds. The Eastern Division of USDA, in cooperation with the industry and other government agencies, has done research to solve many of the problems posed by this new use for animal fats. These joint research efforts have shown that inedible grades of tallows and greases could be so utilized — provided these fats were properly stabilized with suitable antioxidants. Further cooperative research has resulted in the development of effective antioxidant treatments for these fats. Several antioxidants are approved in the U. S. for stabilizing animal fats and vegetable oils. These include, within specified limits, resin guaiac, tocopherols, lecithin, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate, citric acid, and monoisopropyl citrate.

The results of these comprehensive studies have been rewarding. In 1954 about 100 million pounds of inedible tallows and greases were used in mixed feeds; today over 500 million pounds find such usage, with promise of continued expansion. This increasing use of animal fats is off-setting its declining use in soaps. The overall effect has been that the U. S. domestic consumption of animal fats has held rather constant this past decade at between 1.5 and 1.8 billion pounds. Furthermore, prices for these fats have risen from below 4¢ per pound in 1953 to a rather stable demand above 6¢ per pound.

Thus it is seen that two wholly different approaches to finding new uses for animal fats have reached a common goal. In developing an antioxidant carrier for dehydrated forages, the USDA Western Division found that inedible animal fats accomplished several objectives: afforded excellent means of applying the antioxidant, improved the color and reduced dustiness of the finished feed. In looking for new outlets for animal fats, the Eastern Division did research that further established the desirability of incorporating these animal fats in feeds.

*C. Southern Utilization Research & Development Division*

Principal research interests of the Southern Utilization Research and Development Division are in cotton and cottonseed products. Several outstanding contributions have been made to increase the utilization of cottonseed meals for feed purposes.

For a number of years the Southern Division has sought to develop more efficient methods for removing the oil from cottonseed meal. Originally this work was motivated by the four to seven-fold value of the oil over the meal on a pound-for-pound basis. Solvent extraction alone, or in a combination with various mechanical pressing methods, have been investigated. Processes utilizing hexane as the solvent have been developed that leave less than 1 % oil content in the cottonseed meal, the solvent content of the meal is practically zero, and the solvent recovery is highly efficient. The processes also are applicable to soybean and other oilseeds. Most of the U. S. oilseed industry has adopted some version of filtration-extraction processes, with many of them using those developed at the Southern Division.

More recently, studies have been undertaken to determine solvents and conditions that will remove the gossypol and leave the native lysine intact in cottonseed meal. One of the promising leads being pursued is the use of an acetone-hexane-water solvent mixture. Fundamental studies on gossypol are helping to find economical methods for its removal from cottonseed meals and in developing ways to utilize gossypol in industrial products.

Industry has adopted a practical process developed at the Southern Division for esterifying cottonseed refinery «foots» to produce a product useful in feeds. Soybean oil-, peanut oil-, and corn oil-foots also can be used as raw materials. The new product provides a new outlet for the low-cost vegetable oil «foots». The new product is finding ready markets as a high energy additive in livestock and poultry feeds. For example, one U. S. manufacturer is producing 15 million pounds annually.

The Southern Division has done research to detoxify tung meal so it would be suitable for stock feed. Three processes have shown promise, but to date no process has been developed that makes tung meal equivalent in feeding value to other commonly used meals.

#### *D. Northern Utilization Research and Development Division*

The Northern Division has done extensive histological and microscopic studies on cereal grains, especially corn, to furnish information needed for applied milling studies. Research has been undertaken to determine the effects of artificial drying on composition and properties of corn as affecting milling. Milling techniques are under investigation, with special emphasis upon separation of mill fractions of cereal grains by air-classification (turbo milling) to have definitive characteristics desirable for specific end-uses.

Early in World War II, the Northern Division collaborated with British scientists to develop methods for producing penicillin on a large scale. The Northern Division successfully developed an economical submerged fermentation process for producing penicillin which was a major contribution leading to antibiotics becoming available in large quantities. This has been considered by industry to be the foundation of the huge antibiotic industry. In 1957 U. S. antibiotic production amounted to over 3 million pounds, valued at \$3.5 million, with one-fourth going into feeds.

Research is being done to find ways of achieving more efficient use of natural vitamins in feeds and of increasing this supply. In addition to extensive detailed analyses of vitamins in grains and feedstuffs, cooperative work is



being done with geneticists to develop feed grain varieties having greater vitamin content. Processes for the microbial production of vitamin supplements from cereal grains are being developed. Over half of the nearly \$6 million worth of U. S. riboflavin—two-thirds of which is used in feeds—is now produced by the organism and process developed at the Northern Division. Recently, a process was developed for producing beta-carotene to supply vitamin A in feeds.

More than 500 bacteria, yeasts and molds have been surveyed in fundamental studies to explore the possibilities of growing microorganisms on grain substrates to produce feed proteins rich in lysine, methionine, and tryptophan. At least two microorganisms have been found that could produce protein material equivalent to soybean meal. However, economic factors would require that such feed supplements would have to contain about 20 percent lysine in the solids, and, so far, none have been found that approached this amount.

Mention should be made of the internationally known ARS Culture Collection maintained by the Northern Division. This Culture Collection at present contains about 3,500 bacteria, 3,000 molds, and 2,500 yeasts of authentic pure cultures. In addition, there is a «temporary» collection, not yet fully characterized, of some 14,000 strains of microorganisms. This ARS Culture Collection also functions as an official repository for cultures submitted in compliance with U. S. Patent Office requirements for patent applications involving fermentations.

Studies are being made on the fundamental chemical, physical and biological properties of soybeans, with special attention to the minor constituents of soybean oil meal. Another problem of considerable interest is the proper toasting of soybean oil meal to obtain maximum feed efficiency.

A program is getting underway at the Northern Division for screening new and little-known crops that offer good potential for profitable growing on land now producing surplus crops or for meeting needs not satisfied by present domestic crops. One objective is to find new and higher quality proteins, preferably occurring in conjunction with new oils of potential industrial value. Surprisingly enough, detailed compositional knowledge is now limited to only a few hundred of the 250,000 recognized plant species. This vast unknown area will be a scientific challenge for a long time.

## CLOSING REMARKS

In closing, a word should be said about how to obtain details concerning any of the utilization research areas mentioned in this paper. Research findings are made freely available to the public as soon as practical. Most of the research work is published in scientific journals. A substantial part is reviewed in trade journals and popular publications. Much of it is publicized through participation in scientific meetings and conferences with industry and other interested groups. Each of the four Divisions publishes, semi-annually, cumulative indices of publications and patents emanating from that group. The indices, as well as reprints of most of the publications, are

# DIRECTORY OF THE FOUR USDA UTILIZATION RESEARCH AND DEVELOPMENT DIVISIONS

| <i>Division</i> | <i>Director</i>  | <i>Address</i>                                  | <i>Fields of Research</i>                                                                                                                                         |
|-----------------|------------------|-------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Eastern         | Dr. P. A. Wells  | 600 E. Mermaid Lane<br>Philadelphia 18, Pa.     | Animal products: dairy, meat, fats, and leather. Plant products: Eastern fruits and vegetables, tobacco, honey, maple, and new crops. Allergen studies.           |
| Northern        | Dr. F. R. Senti  | 1815 N. University St.<br>Peoria 5, Ill.        | Cereal grains: corn, wheat, barley, grain sorghum, and oats. Oil-seeds: soybeans, flaxseed, safflower, and crucic acid-containing oilseeds. New crops.            |
| Southern        | Dr. C. H. Fisher | 1100 Robert E. Lee Blvd.<br>New Orleans 19, La. | Cotton and cottonseed; tung fruit; pine gum; Southern fruits and vegetables including citrus, sweetpotatoes, and cucumbers; sugar-cane; rice; peanuts; new crops. |
| Western         | Dr. M. J. Copley | 800 Buchanan St.<br>Albany 10, Calif.           | Western fruits, nuts, vegetables, rice; poultry products; forage crops; wheat; barley; wool and mohair; sugar beets; dry beans and peas; castorseed; new crops.   |

All divisions are under the supervision of Dr. G. W. Irving, Jr., Deputy Administrator for Utilization Research and Development in USDA's Agricultural Research Service, Washington 25, D. C.



available free-of-charge upon request. Inquiries may be addressed directly to the particular Division, or to Dr. G. W. Irving, Jr., Deputy Administrator for Utilization Research, Agricultural Research Service, U. S. Department of Agriculture, Washington, D. C.

#### PERTINENT PUBLICATIONS

1. The Feed Situation, (1960 Outlook Issue), AMS, U. S. Dept. of Agriculture.
2. The Fats and Oils Situation, (1960 Outlook Issue), AMS, U. S. Dept. of Agriculture.
3. Agriculture Statistics (1959), U. S. Department of Agriculture.
4. New Uses for Farm Products, Agriculture Information Bulletin No. 209, (1959), ARS, U. S. Department of Agriculture.
5. Alfalfa Saponins (Studies on Their Chemical, Pharmacological, and Physiological Properties in Relation to Ruminant Bloat), Technical Bulletin No. 1161 (April 1957), ARS, U. S. Department of Agriculture.
6. Carotene Stability in Alfalfa as Affected by Laboratory and Industrial-Scale Processing, Technical Bulletin No. , (in press), ARS, U. S. Dept. of Agriculture.
7. Utilization of Fats in Poultry and Other Livestock Feeds, Utilization Research Report No. 2, (August 1960), ARS, U. S. Dept. of Agriculture.
8. Southern Utilization Research and Development Division Research Related to Cottonseed Processing, presented at meeting of Interstate Oil Meal Superintendent's Association, (June 1960) (in press).
9. Filtration-Extraction of Cottonseed Oil — A Staff-Industry Collaborative Report, Industrial and Engineering Chemistry, Vol. 49, pages 920-929, June 1957.
10. Feed Utilization Research — Investigations at Northern Utilization Research and Development Division, Feedstuffs, August 8, 1959.
11. U. S. Department of Health, Education and Welfare publications related to the «Federal Food, Drug, and Cosmetic Act» (as amended).

MODERATOR. Our thanks to Dr. Simpson for the interesting summary regarding research work performed in the United States. Now, Dr. Collinwood will speak about processing and quality of animal feedstuffs.

#### PROCESSING AND QUALITY

COLLINWOOD

Unilever Ltd., London, England

I have been asked to make some observations on the effect of processing on the quality of animal feedingstuffs.

Firstly, I want to make an assumption in a not very well explored area which is, however, receiving attention, to my knowledge, in the United States and in the United Kingdom at any rate. This is the assumption that, with the exception of a few special ingredients (in particular vitamins and possibly anti-biotics), the effect of the processes used to make the raw materials into

finished formula feeds, or compound animal feedingstuffs, is only marginal. (This is not to say by any means that the processing of raw materials *before* they arrive at a compound animal feedingstuffs factory does not have a very marked effect on their performance and the quality of the final feed.) It follows that the ability of the animal feedingstuffs manufacturer to reproduce the quality which is theoretically obtainable depends on his ability accurately to combine the various ingredients available to him so that they will present the designed feed formula to the animal or bird.

If the need for the ingredients, and particularly additives of 1-2 % down to parts per million, being present in the finished product according to the formula is more important to quality than the way in which they are normally treated in an animal feedingstuffs plant, then such quality will mainly depend upon two key processes. These processes are firstly proportioning, which includes selecting the right ingredients and weighing out the correct amounts, and secondly mixing.

We may obtain some idea of what level of quality can be achieved in the proportioning process by considering what the real sources of error are, and these are broadly:

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An unpublished study in the U. K. has indicated that likely errors in weighing are sufficiently over-shadowed by the variations in raw materials commonly available in that country to rule them out as a major source of error, provided mechanical feeders are used. (It has not proved possible to gain a true estimate of probable error when using hand-operated slides. Spot checks show that at the worst this may be serious but not too frequent.)

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Control of the right selection of ingredients to avoid any omissions may be built into the plant by using punched cards. This is probably worth while when considering trace ingredients, vitamins, drugs, minerals and so on. Generally they are not subject to so much variation in quality; they are required in small quantities; they are expensive; and they are each quite vital to the performance of a feed, hence the most elaborate type of plant may be justified for their inclusion.

The conclusion arrived at was that, in the U. K. at any rate, suitably designed plant can virtually remove chances of error in the addition of feed additives for any reason other than gross negligence, but that protein content can vary uncontrollably with one standard deviation of as much as 0.5 %.



The next problem related to quality is mixing, and the efficiency of the mixing operation is not an easy one to measure. However, some indication of the route towards optimum quality may be gained by considering what happens in the mixing operation. It may be convenient to regard mixing in two senses:

- (1) Local mixing, which can be expressed in terms of a deviation of one small sample from another taken quite close to it in a mixer; and
- (2) Coarse mixing, which can be expressed in terms of the deviation of one small sample from another taken from a distant point of a mixer.

This permits the concept of homogeneity as having been achieved when the deviation between the samples taken far apart is no greater than the deviation between samples taken close together.

Most mixers designed with adequate internal mechanical transport are capable of approaching homogeneity in this sense, but this still leaves us with the problem of saying that is an adequate standard of local mixing. It is well known that a certain lack of homogeneity is easily catered for by storage of vitamins and nutrients in the body of an animal or bird, but I would like to stress that it is most important for the designing of plant to provide the highest «economic» quality, i. e. satisfactory mixing with the cheapest plant, that more should be known of the tolerance of animals and birds to variations in their rations.

A limited series of tests have suggested that homogeneity cannot be quite reached in practice. It seems that, when the mixing operation starts, local variations are reduced first and the ratio of the gross variations to local variations is high, being of the order of 10. This reduces in from 3/15 minutes, depending on the type of mixer, to a fairly stable figure of about 1.3, and after this happens both the local and coarse variations reduce together. Finally, a degree of local mixing is reached which is probably determined by the nature of the ingredients in the mixture.

The relative size and shape of particles to be mixed is of great importance. Severe regressions in mixing efficiency have been found in mixtures which show a marked disparity in size and shape, such as would occur in mixing corn and fine-ground soya meal, for example. The range of densities with which we are concerned, however, does not seem to be very significant.

The question of mixing trace ingredients has received a considerable amount of attention. Two methods are advocated. Either the ingredients are mixed dry, or they are mixed as suspensions or solutions in liquids. Adding trace ingredients in liquid form has some undoubted advantages. Metering is easy, contamination can be avoided and there same good high-speed liquid mixers, and, by pumping them in at the last stage of manufacture, losses are avoided. The limit to which the process can be used is provided by the amount of moisture which can be added to a feed. Dry mixing can, however, be done satisfactorily and seems to have found favour in a number of countries, highest efficiencies being gained when the powdered additives are added slowly to a mixer. I am not aware of any published work on the relative mixing efficiencies of these two methods.

I have spoken of the key processes which may cause limitation in quality of animal feeds. The subject is, however, but superficially explored. It will

not be until we know a great deal more about the tolerance of animals and birds to variations in the properties of the feeds which are so carefully designed for them that very much more progress can be made towards determining what is the optimum economic quality obtainable.

MODERATOR. We thank Dr. Collinwood for his interesting communication. Practical investigations are being performed in the United Kingdom regarding processing techniques, specially as regards errors in raw materials, errors in weighing out the correct amounts etc., and role with respect to those techniques for better homogeneity in the mixtures. Thank you very much, Dr. Collinwood. Now, Dr. Nogues will read his report on «Manufacturing of Mixed Animal Feeds in France».

## ✓ MANUFACTURING OF MIXED ANIMAL FEEDS IN FRANCE ✕

BY

DR. JEAN NOGUES

U. F. A. C.

France

### I. THE ROLE OF FEED PRODUCTION. EVOLUTION AND TRENDS DURING THE LAST 10 YEARS

The manufacturing of mixed feeds in France has registered a special expansion after the end of World War II, particularly so after 1949.

Feed production went from 330,000 tons in 1949 up to approximately 2,300,000 tons in 1959, which means it has been multiplied by 7 in a period of 10 years.

The volume of business corresponding to the tonnage produced during 1959 exceeds one thousand million new francs.

Within the European economic framework, the comparative importance of French production is considerably less than Great Britain's, and less than that of Germany and Holland.

#### *PRODUCTION OF MIXED FEEDS IN EUROPE DURING 1958*

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|                      |                |
|----------------------|----------------|
| GREAT BRITAIN ... .. | 7,300,000 tons |
| GERMANY ... ..       | 2,900,000 tons |
| FRANCE ... ..        | 1,955,000 tons |
| BELGIUM ... ..       | 1,300 000 tons |
| ITALY ... ..         | 500,000 tons   |

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## II. STRUCTURE — SIZE OF MANUFACTURING PLANTS

Feed production in France is assured by a little more than 1,000 factories distributed all over the country.

During 1959, the average production was slightly more than 2,000 tons per factory, per year, which is a very poor average.

The small and medium size enterprises have endeavoured to survive, either by affiliation to service organizations of national scope, or by grouping themselves into cooperative movements which perform for their member companies a series of technical and consulting services, sales promotion activities, etc.

The total production is very unevenly distributed among the different companies; for example, in 1958, according to the available statistics, France had:

- 5 factories which accounted for more than 30,000 tons per year (about 20 % of total tonnage).
- 19 factories producing 15 to 30,000 tons a year, accounting for 20 % of the total production.
- 79 factories producing from 5 to 15,000 tons per year (approximately 30 % of total production).
- 967 factories, producing less than 5,000 tons per year, which accounted for about 30 % of the total production.

Therefore, according to the above mentioned figures, 103 factories, i. e., about 10 % of the total number of French companies, have produced in 1958 70 % of the total tonnage of mixed feeds. This provides a rather accurate idea of the distribution of French production in this important field.

With respect to geographic location, French enterprises were first established near the sources of raw materials, which explains the location of a good number of plants on ports of importation. In many cases, such industries were established in the neighbourhood of factories producing subproducts, such as oil plants, flour mills, etc.

However, in recent years these feed manufacturing centres have shown a trend to approach the cattle breeding areas, that is to say, to find locations closer to the consumers, in order not only to reduce distribution costs but also to be able to render an improved «after-sale» service to their customers.

## III. DISTRIBUTION OF PRODUCTION ACCORDING TO TYPE OF FEEDS AND RAW MATERIAL USED

In 1958, including molasse type of feeds consumed essentially by bovine cattle, production amounted to 1,955,000 tons, distributed as follows:

|                      |        |                                                                     |   |   |
|----------------------|--------|---------------------------------------------------------------------|---|---|
| Bovine cattle ... .. | 20.7 % | of total tonnage                                                    |   |   |
| Lambs ... ..         | 0.6 %  | »                                                                   | » | » |
| Pigs... ..           | 27.6 % | »                                                                   | » | » |
| Poultry... ..        | 49.5 % | »                                                                   | » | » |
|                      |        | (of this, 1/3 in laying hen feeds and 2/3 in BROILER feeds, approx. |   |   |
| Miscellaneous ... .. | 1.6 %  |                                                                     |   |   |

The following raw materials were used, quoted in decreasing order of importance:

|                                                                                    |        |
|------------------------------------------------------------------------------------|--------|
| 1. Cereals ... ..                                                                  | 45,6 % |
| Barley, corn, wheat, oats, rye.                                                    |        |
| 2. Other hydrocarbonized products ... ..                                           | 9.1 %  |
| Molasses, rice bran, manioc, carob beans, other.                                   |        |
| 3. By-products of cereals ... ..                                                   | 17 %   |
| By-products of flour mills, by-products of corn.                                   |        |
| 4. Cakes ... ..                                                                    | 16.7 % |
| Groundnuts, soybean, palm, linseed, copra, rapeseed, sunflower, cottonseed, other. |        |
| 5. Animal proteins ... ..                                                          | 6 %    |
| Meat meal, fish meal, milk and serum powder, fish solubles, other.                 |        |
| 6. Additives ... ..                                                                | 5.6 %  |
| Dehydrated alfalfa meal, vitaminized mixed minerals, etc.                          |        |

After 1958 there appeared a series of clearly defined trends in the consumption of several raw materials, and particularly a marked increase in:

- consumption of corn as compared to consumption of other cereals, barley especially.
- importance of soybean cakes, the use of which is constantly increasing, especially as compared to sunflower cakes.

Finally, it seems that the amounts of fish meals consumed have registered a considerable increase with respect to other sources of animal proteins.

#### IV. THE ROLE OF MIXED FEEDS AND ANIMAL HUSBANDRY IN THE FRENCH ECONOMY

Always quoting from 1958 statistics, it is noted that animal productions have represented 60 % of the agricultural income against 40 % only of vegetable production; its value has increased to over 19 thousand millions of New Francs, approximately half of which are for beef, a third for dairy products and 1/6 for poultry.

This total figure amounts about the same as the products of the metal working industries (20 thousand millions of New Francs), more than 50 % of the chemical industries (12 thousand millions of New Francs), and 3 times over that of the automobile industry.

The products of the cattle industry, therefore, have a top position within the framework of the French economy; in spite of which, mixed feeds occupy a very low position, being estimated that of the total of feed units consumed by the animals, only 3 to 4 % approximately come from mixed feeds.

This situation, in our opinion, may be explained in the following way:

— In our country, fodder production plays a very important role in the production of beef and dairy products, which in France are essentially considered as a process industry for converting the animal feeds from the agricultural concerns.



— By reason of the lack of specialization of a great number of farming concerns which combine agricultural and cattle breeding activities, being therefore self-consumers of their own cereals.

In most cases, such farms only buy nitrogenated products.

— Because of the poor intensification of some farms aiming to cattle breeding, located in areas which are poorly developed as yet in the technical field.

## V. ORGANIZATION OF THE FRENCH MIXED FEEDS INDUSTRY

Most companies are affiliated to National Syndicates.

Such Syndicates have established two central agencies, namely:

— The National Federation of Animal Feed Industries Syndicates.

— The Professional Institute for Research and Control of Feed Industries.

The National Federation deals mainly with problems of an economical nature, and serves in a certain way as representative of the manufacturers near the government agencies, providing the necessary contact with other specialized bodies, agricultural and other.

The Professional Institute for Research has the objective of studying those technical problems of interest for the whole industry, promoting research for the purpose of improving feed efficiency, and controlling the productions manufactured by their member companies; this is done by testing and analyzing manufacturing samples in the laboratories of the National Institute of Agronomic Research. The results of such analysis must conform to the specifications and standards established by the Professional Institute of Research, whose decisions supplement and determine the action taken by the Services of Fraud Prevention in this field.

## CONCLUSIONS

### VI. PRESENT TRENDS AND ANTICIPATED DEVELOPMENTS

It is reasonable to expect an increase in mixed feeds consumption in France.

In our opinion, there are several reasons which will determine such increase:

— By reason of the diffusion of technical progress and development in the rural areas, production methods are being improved day by day; this development being followed almost without exception by an increase in the purchases of animal feeds.

— French farmers are orientating their activities to an ever increasing specialization; particularly the big cereal production concerns show a tendency to reduce, and even eliminate altogether, cattle breeding in order to concentrate their efforts on agricultural products.

On the contrary, several areas of France, generally covered by small and medium size farming concerns, follow a contrary trend. In these areas, the land used for cereal production is being reduced, while areas used for pastures are increasing, as the farmers limit their activities almost exclusively to cattle breeding, which results in an increase of their purchases of mixed feeds.

Finally, the scarcity and high cost of labour force the farmers, not only to specialize their production but also to look for the most simple solutions to their production problems. Of course, mixed feeds are a very useful means for solving their problems.

We believe that in the near future, mixed feeds manufacturing in France will continue and maintain the tonnage progression registered during the last ten years.

This development will be accompanied by a corresponding improvement in the structure of farming concerns, for the purpose of getting a greater efficiency.

## DISCUSSION

MODERATOR. Thank you very much, Dr. Nogues for your excellent presentation, which I do not doubt will raise many questions from your listeners. I think it would be most interesting to establish comparisons between this system and the ones used in our respective countries.

*Dr. Simonnet* (France). I think Dr. Nogues' report does not need any comment. I only would like to congratulate him on his very interesting presentation. I think we should emphasize that the French mixed feeds manufacturing industry is not a backward one, and that it has a lot of possibilities if all factories join their efforts for the purpose of adopting modern methods. There is also a lot to do in the area of consumer education. This is already being done and will give very good results. It is also necessary to establish pilot breeding centers. This is a problem which will be only be resolved if the mixed feeds industries follow the progresses indicated by Dr. Nogues. Thank you very much.

MODERATOR. Any other comments? Then if I may very briefly, I would like to supplement this information by referring to what has been done in my own country, Belgium, where we have a mixed feed industry which is comparatively well advanced. In the last few years our production has registered a very important increase. In 1943 Belgian mixed feed production was 695,000 tons: by 1958 it was 1,200,000 tons. Mixed feed production is distributed in the following way: 1/3 for beef cattle, 1/3 for swine and the remaining third for poultry. Now, before the next speaker starts reading his report, I would like to know if there are any other comments on this subject.

*Dr. Collinwood* (U. S.). The mixed feed industry in the United Kingdom has registered a remarkable increase in recent years. I think our figures were 4 millions tons in 1953, as compared to eight millions and a half at the present time. Now I would like to ask a question from Dr. Nogues. He stated that almost 50 % of mixed feeds manufactured were used for poultry consumption. I understand that poultry feeds need a much more accurate process than swine feeds. Are there any new developments in France for processing this type of feeds?

*Dr. Nogues* (France). We have now in France a certain number of automatic and semi-automatic plants. The present trend in France is for automatic processing.

MODERATOR. Any more questions. Well, then Dr. Peruchon de Brochard will read his paper on «Public Relations in Feed Marketing».



FRANCE: PUBLIC RELATIONS IN THE FIELD OF MIXED FEEDS  
MANUFACTURING AND ANIMAL HUSBANDRY

BY

M. PERUCHON DE BROCHARD

President, «Association Scientifique du Bureau de Nutrition Animale»  
France

Mr. Nogués has just explained to you the present syndical and professional structure in France regarding this subject. However, he has not talked to you about the remarkable educational task performed by these institutions, and specially by the «Institut Professionnel de Recherches». This Institute has not only done a wonderful job of educating the manufacturers, providing them with all kinds of information, standards and specifications, but also has endeavoured to inform and educate the public, the customer, that is to say, the individual breeders that buy mixed feeds; this work has been carried out by means of promotional materials, pamphlets, newspaper articles and specialized exhibitions in most French towns and cities. It can be said that one of the reasons for the remarkable increase in mixed feed production in France — which has grown seven-fold in ten years as mentioned in the preceding report — is a direct outcome of these promotional activities.

In addition to the «Institut Professionnel» there are other organizations which have also played a very important part in the Public Relations field. An Interministerial Commission has been established in France, headed — by the way — by Professor Simmonet, well known to all of you, the purpose of which is, essentially, to advise the French Government as to the approval or rejection of additives in mixed feeds. This Commission has become very important in our country at a time when animal productions are being attacked by a certain sector of the press, often referred to as «naturalist press» campaigning both against the use of fertilizers in vegetable productions and also opposed to animal productions obtained by means of mixed feed utilization. This Commission has enabled us to fight back such adverse campaigns by advertising in the French press that the interests and health of the final consumer are protected in our country by a reliable Government agency manned by highly qualified technicians, the best scientists in their field, which is the best guarantee that our animal products are quite sound and fit for consumption, as the mixed feeds administered are most adequate and safe.

If you allow me a brief digression from my main subject, I would like to say a few words about the convenience of establishing such a Commission on an international level in order to avoid a shortcoming which all of you have been able to note through preceding reports: I am talking about the wide differences in opinion regarding the use of additives in the different countries.

I am trying to call your attention as to the real need, in European countries, for an agreement on this subject, because, with the Common Market, certain

custom barriers would increase indirectly if animal productions were to be obtained in different countries through different means.

All these French organizations — I am referring to the ones created by professional people — have a common characteristic, which is their spontaneous nature. Thus, the mixed feed manufacturers themselves have placed their activities under the control of their Institute. They do not only pay the bill but also accept the Institute's control.

I might mention another French organization — the «Bureau de la Nutrition Animale» — of which I have the honour to be the President; this body has been created by the professional people themselves, that is to say, breeders and manufacturers of mixed feeds. Ours is a free organization, open to everybody, its objective being to collect all kinds of technical information likely to promote and improve mixed feed manufacturing, and technical documentation for selling breeders on the advantages of buying and applying mixed feeds in their productions.

It was necessary, therefore, to carry out a dual task of disseminating information and promotional activities: to provide interested manufacturers with all the technical data necessary to their activities, and to perform a similar job for the breeders on the practical level, namely, selection, housing, materials, methods and processes, etc. In the last instance, if the feeds are good and the breeding methods adequate, the breeder will make money and the mixed feed industry will prosper.

Let us talk now about some of the most outstanding developments registered in the field of Public Relations during the last few years through the activities of the organizations I have just mentioned; all of these organizations have the common characteristic of being non-governmental agencies (I am not referring to the Interministerial Commission) but private associations intended to serve the professional interests of this industry, managed by professional people.

Six or seven years ago, the animal nutrition industry was savagely attacked by French manufacturers of Gruyère cheese. Many articles were published in the French regional press claiming that mixed feeds hindered the production of good-quality Gruyère cheeses. What course did we take? We just organized a congress, under the direction of Professor Leroy, held in Besançon, with the participation of the main professional organizations. In this way, we were able to prove that mixed feeds were not responsible for certain shortcomings found in Gruyère cheese manufacturing, but that such difficulties were simply due to inefficient milking methods. This is a very good example indeed of Public Relations.

More recently we had to endure another adverse campaign, especially from the French press, complaining about the poor quality of poultry meats; several newspapers originated a great scandal claiming that the guilty animals had been administered hormones or arsenical products, dangerous for human consumption. In this disagreeable case we benefited from the help provided by our Interministerial Commission for Animal Nutrition; we were able to show legislation to the effect that the use of such products in animal nutrition was forbidden. Thus, the public regained their peace of mind and mixed feed sales did not drop.

Following this scandal several sectors of opinion demanded the elimination of animal proteins from mixed feeds; the technicians of the «Bureau de



Nutrition Animale» were able to develop sound all-vegetal formulas, with a main basis of corn and soybean oil cake, formulas that have been adopted by several important breeding centres. I may mention, for example, the case of the Bress area, well known by the production of high-quality poultry; existing regulations in this area establish that mixed feeds will only contain vegetable substances, with the natural exception of milk.

I am going to talk now about a more recent development, not yet reported. I feel very happy to present here the first news about this case, as it will serve the interests of the Soybean Council, of which we are the guests. This year, a certain number of accidents were reported regarding chickens fed with soybean cake extracted using trichlorethylene. This product is, as you well know, a solvent substance. As traces of trichlorethylene were found in the suspected rations, there were strong reasons in support of the belief that this product was responsible for the mentioned accidents, although no definite proof could be produced to that effect. We called a meeting of the soybean cake industry and presented the problem to them (In this respect I am talking as President of the Bureau of Animal Nutrition), and I am happy to say that before leaving for Spain I was informed that the use of trichlorethylene had been abandoned by those plants that had not done so before. Again, this is another success of our Public Relations activities, inasmuch as such a conclusion will undoubtedly restore the confidence of the breeders.

Within our organization, I would like to emphasize the reorganization of the veterinary profession, which has created a specialized section maintaining a very close cooperation with the other organizations. For this reason several conferences have been jointly organized, with the participation of both veterinary technicians and mixed feeds manufacturers.

With respect to our Bureau of Animal Nutrition, we will hold in 1961 our XV Annual Conference, which will be attended by manufacturers of mixed feeds, breeders and equipment manufacturers. These meetings take place very often, and gradually have become internationalized; at present we have a wide participation from Belgium, Italy, Spain and Switzerland.

I have brought with me a few colour photographs of the Centre of Experimental Research established by the Bureau of Animal Nutrition, to show one of the achievement of our organization, financed by funds provided by the breeding industries and the manufacturers of equipment and mixed feeds. This Centre is not, properly speaking, an organization for purely scientific research (we have other organizations for such purposes, as for example the one at Jouy, in the Jura, one of the best in its kind), but an organization where individual manufacturers can submit samples of their products in order to have them tested on live animals, and compare with that of standard feeds, the formulas of which are published and manufactured at the Centre itself.

During a trip to the United States I had the idea to collect documentation and various data regarding this type of tests. I had been the guest of Pfizer, Salisbury and many others, and had had the opportunity to see what they had done regarding this kind of tests.

The Centre at Aix is not yet finished, however, it has been working for over one year; it has performed hundreds of tests for the mixed feed manufacturers, while the breeders send us their best animals for control purposes.

We even have tested rearing equipment such as feeders, watering systems, pens, etc.

In this way we have endeavoured to test at the BNA Centre on behalf of the soybean cake manufacturers the biological value of their products on the basis of their individual methods of production. This has enabled us to discover significant differences which in turn have enabled the manufacturers to revise their production processes in the light of these new developments.

## DISCUSSION

MODERATOR. We want to thank Dr. Peruchon de Brochard for his information of the public relations field in France. Any questions please?

*Dr. Manuel Gallo* (Spain). The speaker has mentioned some additives that are forbidden for mixed feeds manufacturing in France. I would like to know whether he refers to certain chemical additives or to natural additives that may be considered as feeds. I would also like to know if he could mention some additives that have raised any doubts in this respect, and reasons for such doubts. He has also mentioned about arsenic products and some hormones being forbidden for mixed feed manufacturing, and I would like to know what is the situation in France in this area.

*Dr. Peruchon* (France). If I have understood your question properly I can say that in France any additive that is not specifically authorized may be considered as forbidden: the lack of legislation does not authorize the use of a product. Ureas, hormones, everything that I have not mentioned is forbidden.

*Dr. Cid* (Spain). Just one specific question, please. I would like to know what ventilation systems do you use in your coops for broiler raising, specially for battery breeding?

*Dr. Peruchon* (France). In the small buildings we use, of about 40 square meter surface, the problem of mechanical ventilation does not exist: we have windows, many of them in both the North and South sides, and also, the animal population inside the building is not high. Of course, my answer would be quite different if we were talking about industrial coops, with a high animal population, which would absolutely require mechanical ventilation.

*Dr. Cid* (Spain). Have you ever used electric air extractors?

*Dr. Peruchon* (France). We do not need them in small buildings, as we have ventilation from the north and south sides. Natural ventilation is perfect for us. Of course, were our buildings larger, we would need mechanical ventilation.

MODERATOR. Well, as there are no more questions on this subject we will proceed. Dr. Andreas, from the United States will talk about «Feed Merchandising in the United States».



## FEED MERCHANDISING IN THE UNITED STATES

Dr. D. O. ANDREAS  
U. S. A.

In the quest for lasting world peace and brotherhood, food is one of the great catalysts. Our meeting here in Madrid is an illustration. Here, we — businessmen, scientists, government officials — are drawn together to unite our best efforts in seeking out answers to common problems and in exchanging information of benefit to all people.

Although we come from different lands and may have differing native tongues and customs, we do have common problems and common goals in the work of producing greater supplies of more nutritious animal foods at lower costs.

Scientific advancement has shrunk distances so that but a few hours flight can bring us together for a conference such as this. Likewise, scientific research in each of our countries is making amazing strides in the field of animal nutrition and we know that all of mankind can benefit from the pooling of our information and experiences in this work.

We have the satisfaction of being in a good cause. Better animal nutrition means better human nutrition and better human nutrition means opportunities for fuller development of all human resources around the world and an allaying of the tensions that trigger strife and conflict.

Just a little over three months ago there was launched — just a few hundred miles from here, in Rome — a five year world-wide «Freedom-From-Hunger» campaign under the auspices of the United Nations Food and Agriculture Organization. FAO Director General, Binay Ranjan Sen, described it as an «historic campaign for the eradication of hunger in its manifest and hidden forms.» The reason for this renewed attack, he said, lies in the fact that «more than half the world's population does not have enough food or the right kind of food. Many go hungry. Others suffer malnutrition, which leads to ill health and impaired capacity for work.»

Another well-qualified observer, Dr. Sherman E. Johnson, chief economist of the Agricultural Research Services of the U. S. Department of Agriculture, recently served as chairman of the Ford Foundation Team which studied food problems in India. He has written that «The greatest unsolved problem of our times is the abject poverty of the masses of people in the less-developed countries. Their continuous struggle for food is a primary cause of international instability.»

We are adding 50 million more people to the world population each year. To raise the food and other farm products people need, a little more than 1.25 acres of arable land was available per person for the world as a whole in 1955. If the world population increases, as the experts predict, to around 6,280 million by the year 2,000, the amount of arable land will have been reduced to just over one-half acre per person.

The facts are plain. There is — and will continue to be — around the

world a desperate need for more animal protein foods — more milk, eggs and meat. This is true for vast numbers of people in the under-developed nations and for many right in our own countries.

Greater efficiency in animal nutrition will bring added benefits in the better health of our people at home. And the lessons we learn about this important subject must be transported, through FAO and other humanitarian organizations, to help people of less-developed lands, where a dread disease such as *kwashiorkor*, the protein-deficiency ailment, can still snuff out the lives of little children and lives of many and prematurely because of malnutrition.

In my own country we have made amazing, heartening strides in developing animal agriculture. The advances have come through great teamwork — the basic research of our land grant colleges and government research stations, the feed companies and the farmers.

Today, two-thirds of the protein consumed by Americans and two-fifths of their intake in calories come from animals. These nutrients in meat, milk and other dairy products, and in eggs and other poultry products — round out the well-balanced American diet.

The result of better farm practices, breeding, feeding and managing livestock has been a trend toward more pounds of product for less feed consumed.

To cite an example, it took 18 percent fewer feed units to produce 100 pounds of milk in 1956 than it did on the average during 1940-44. It took 12 percent fewer feed units to produce 100 pounds of meat as cattle and calves, 13 percent fewer feed units to produce 100 pounds of eggs, 32 percent fewer feed units to produce 100 pounds of broilers, and 4 percent fewer feed units to produce 100 pounds of pork.

The most dramatic story in the poultry industry has been the evolution of the fast-growing broiler bird through breeding experiments by poultry scientists of the U. S. Department of Agriculture, state agricultural experiment stations and private companies. The effect has been to raise greatly the efficiency of converting feed to meat. Out of this development has grown a tremendous commercial broiler industry of about a billion dollars a year. Back in the Thirties, it took 14 to 16 weeks and about 15 pounds of feed to grow a 3-pound chicken. Today, some commercial growers are producing choice 3-pound birds in a little over eight weeks on as little as seven pounds of feed.

In the Thirties it used to take about 7.5 pounds of feed to produce a dozen eggs. Many feeders today produce a dozen eggs on a little more than three pounds of feed.

Broiler and egg production have become large-scale, specialized operations, requiring considerable capital.

Out of these developments have come an abundance of poultry and eggs. They are staple foods at prices making them good buys for consumers.

Another significant step in the poultry industry has been the Beltsville white turkey. Here, USDA scientists got a small, meaty bird that would be useful to small families. Turkey, too, is becoming a year-round staple food.

Today, good feeders in our country are producing a pound of beef for an average of less than 7.5 pounds of feed. Back a generation ago, it took an average of 10.9 pounds of feed to produce a pound of beef.

Today, good hog raisers feeding good commercial supplements are producing



pork at the rate of one pound of meat on about 3.2 pounds of feed, in contrast to a generation ago when pork was being produced on an average of 5.1 pounds of feed for each pound of meat.

Increasing production continues to dominate the American farm picture. Average per acre yields and production per livestock unit — milk per cow, eggs per hen, meat per unit of feed — increased by a third from 1935-39 into 1957. Output per man-hour of farm labor doubled over the same period of time. Government studies show that during the past 10 years American agriculture has increased its productivity an average of 6 percent per year, while the rate of increase for the rest of the economy has been only 2.8 percent.

It seems clear that we in the U. S. have been moving in the direction of an «animal agriculture» — one which centers attention on meat, milk, and poultry and cuts down the acreage devoted to the direct cash crops that have been in surplus supply. This shift in production is associated also with the main shift in food-consuming habits.

From 1935-39 to 1956-58, Americans increased their per capita consumption of animal products by almost 100 pounds on a retail-weight basis — including 22 pounds of beef, 6 pounds of pork, 5 dozen eggs, 13 pounds of chicken, 3 pounds of turkey and 45 pounds net of fluid milk and other dairy products (excluding butter).

On the other hand, consumption of other foods, chiefly potatoes and grain products, has declined by almost 100 pounds (including 15 pounds of cornmeal, 41 pounds of wheat flour, 28 pounds of potatoes, and 12 pounds of sweet potatoes).

So, potatoes and grains have given way to livestock products, meat, eggs and milk.

Projections of future average per capita food consumption indicate, according to economists in the U. S. Department of Agriculture, a further modest improvement in the overall quality of American diets. They look for the average per capita use of cereals and potatoes to continue to trend slightly down for some years yet and for consumption of eggs, sugar and fats to hold about constant. They say dairy products (other than butter), fruit, vegetables, poultry and red meat may show some further increases.

In 1959, Americans consumed, per capita, 87.3 pounds of beef and veal, 68.3 pounds of pork, 4.5 pounds of lamb and mutton, 28.8 pounds of chicken, and 6.0 pounds of turkey. In addition, they each ate an average of 347 eggs and consumed an average of 341 pounds of fluid milk.

This abundance of food has been produced by American farmers, aided by advances in technology. It has made food a bargain for the consumer. Our food costs us less, in terms of human effort, than that of any people in the world. I noticed some figures from the U. S. Department of Agriculture recently which show that it costs an average industrial worker in the U. S. only one hour's pay to buy a normal meal for four persons. This normal meal — consisting of beef sirloin, potatoes, cabbage, bread, butter, milk and an apple — can be had for 60 minutes' industrial labor.

Consumers in the U. S. are spending about 21 percent of their income for food. This percentage is slightly below that prior to World War II, even though food consumption per person is about 13 percent higher and consumers are purchasing more marketing services with their food. If consumers were purchasing the same quantities and qualities of food per person as in the late

1930s, food expenditures would account for only about 15 percent of disposable income.

So, the farm revolution has been good for the U. S. consumer. It has resulted in a situation in which only about 10 percent of the work force in agriculture in producing food for the rest of the nation, enabling more people to be free to produce cars, television sets, air conditioning and other goods. In contrast, for Europe as a whole, it is estimated that 23 to 25 percent of total employment is in agriculture. The Soviet Union is said to be devoting about 40 percent of its labor to agriculture.

In 1940, each farmer in our nation turned out enough food and fiber to support 11 persons. Today, he produces enough for about 24 persons.

Any way you look at it, agriculture deserves much credit for the higher standard of living we enjoy.

But, the abundance that has blessed consumers has also served to depress farm prices and farm income. Farmers in the U. S. have found their incomes sagging while those for the rest of the population have been forging ahead.

As a result, you will find, in reading news bulletins from our country, that the farm issue is now being debated as a key issue — up and down the land — in the presidential campaign that is reaching a climax about this time.

The farm vote remains an important factor despite the decline in numbers. And both Republican and Democratic candidates have presented what they argue are better solutions to help farmers get a fair return for the tremendous job they've been doing.

Aiding farmers in that job has been the commercial feed industry. It has become the largest industry serving agriculture, with an annual volume of around 3-1/2 billion dollars. It has helped animal agriculture, the production of animal and poultry products, grow to annual volume of 18.8 billion in 1959. Last year, livestock and their products accounted for 55.7 percent of farmers' cash receipts from marketings of farm products and government payments.

In my own state, Minnesota, livestock and livestock product sales account for more than 70 percent of farm income, and for a roughly comparable percentage in the whole of the North Central states.

I would like to draw your attention to one very significant feature prevalent in American feed merchandising; that is, the use of credit by feed companies to finance the farmers.

It has become commonplace for feed companies to sell their feed to farmers on a basis which does not require the farmer to pay until the poultry or livestock goes to market. In some cases, feed companies even go so far as to furnish the money to farmers to buy the baby chicks or turkeys and lend additional capital for the purchase of equipment.

This extension of credit has been the backbone of the rapid expansion of poultry and turkey production. Along with it usually goes the offer of a complete service. That is, a man representing the feed company who calls on the farmer regularly, examines and counts his flock, inspects it, recommends medicine, management practices, etc. This complete service technique is the key to selling, and the feed companies who have pursued this policy under good management have increased their feed tonnage at a remarkable rate. It is my belief that the complete service technique of selling is the key to expansion of feed usage.

The feed industry in the U. S. has increased its tonnage from 29.1 million



tons in 1950 to 40 million tons in 1959. It's estimated that production in 1970 will be at 55 to 65 million tons. And, as I've pointed out before, the increase has been occurring during a time when feed efficiency has increased sharply.

So, the record is clear. The feed industry has played an important role in the growth of American agriculture. It has been a partner in giving to Americans a more healthful diet to undergird the productiveness of the whole economy. We are proud of that role and we believe it will be even greater in the years ahead as we apply more and more the discoveries and developments of research.

We hope to help other nations progress, too, in attaining better diets. Our «food-for-peace» programs and the technical aid we offer through United Nations agencies are ways by which we can translate our good intentions into action. And, conferences, such as this one, bringing industry, science and government from our lands together can be mutually beneficial. We, despite our progress, have still a long way to go in supplying the food the world is to need.

Animal nutrition contributes to human nutrition, as we well know. I want to close with a comment made about the role of nutrition by that great scientist and physician from Scotland, Lord John Boyd-Orr. He said:

«The new science of nutrition does more than show the way to better health and improved physique. It affords a solution to some of our most difficult social and economic problems. If its exponents speak with the authority warranted by the knowledge which they have acquired in recent years and use all their influence to get this knowledge applied, a review on nutrition and human welfare ten years hence may be a record of unprecedented advance in human welfare.»

Our challenge is to be a partner in contributing to that hoped-for advance in human welfare.

MODERATOR. Thank you very much for your report, Dr. Andreas. Now I think it would be convenient to listen to Dr. Logan's report after which we will have a question and answer period on both papers.

## SELLING THE PUBLIC

BY

JOHN A. LOGAN

Management Council, President, National Association of Food Chains  
since its inception, U. S. A.

I am proud to participate in this Symposium on a topic of such universal interest and far reaching importance to people everywhere. The subject assigned to me is especially appropriate for this Merchandising discussion. Public approval and patronage are, needless to say, essential to the success of any enterprise selling food products. Such approval is based on confidence. It is clear to us in the U. S. A. that to obtain and hold public confidence

requires cooperation and understanding of all factors in the farm-to-table team — the producer, the feeder, the processor and the distributor. To us this means the farmer or rancher who raises the animals, the feeder who finishes them for market, the manufacturer who processes and/or packages the product, the wholesaler and the retailer who make the product available to the consumer. Let us now understand that the consumer — that is everybody — is the customer upon whom everyone on this team depends for success. Now just how do we gain and hold public confidence — or consumer patronage? Well, let us explore this question briefly.

People like to do business with people they like. But the processes by which you get people to like you may not be simple. Public opinion is the combination of many likes, many attitudes, many acts. Public opinion determines where people spend their money day after day; public opinion influences what stores will be profitable, what stores will fail.

A retailer — especially a food retailer — more than almost any business, is dependent upon favorable public opinion for success. The food retailer is the last link in the chain from farm to table. If quality, price or service are unsatisfactory, chances are the retailer — not the farmer or the manufacturer — will be blamed and penalized by loss of business. The retailer has, therefore, a great responsibility in several directions. He has a primary responsibility to customers. He has responsibility for proper choice of suppliers. He has responsibility for maintaining the pride, dignity and satisfaction of employees. He has a responsibility to the community in which he operates. He has responsibility to compete fairly and thus win the confidence of other merchants. The successful retailer truly must «win friends and influence people».

Let us now consider especially relations with suppliers for mutual benefit over a long period as well as today's dealings. All should work together in the public interest to balance supply and demand, to develop and to market new products, and cooperate on modern packaging. It is important that producer, supplier and retailer have a fair profit and that customer acceptance and confidence be maintained.

Numerous examples could be given of food manufacturers and food retailers working together to develop and market products, for which demand has been indicated by homemakers. Many other instances could be cited where manufacturers get retailers to «test» new products in limited market areas to determine customer acceptance of product, or package, or price, or other essential but unknown elements. Cooperation between manufacturer and distributor has many advantages for both — and in the long run for the public. Each is dependent on the other.

Perhaps an outstanding example of cooperation between supplier and distributor, is the coordinated program for marketing farm products in abundant supply. This program was started in 1936 as a result of a conference between important American farm leaders and leading chain food distributors through the machinery of the National Association of Food Chains. It was pointed out to both groups that their interests were mutual, that each could help the other achieve a common goal, larger food consumption, higher standard of living for the public and larger sales and profit for farmers and retailers. Over 350 campaigns and promotions involving almost every edible farm product have been conducted at the request of producers.

Successful food retailers in the U. S. A. have developed programs and



methods to protect their customers and to give them assurance that their needs and wants will be satisfied. «Satisfaction guaranteed or money cheerfully refunded» is more than a phrase in American food retailing. It has become almost universal policy and common practice generally among food retailers. It costs very little — so little it is not measurable in percent of sales — but it has done a great deal to create customer confidence and to assure employees that the company means what it says in its statements and advertisements about policies and practices. It is another way of saying what the successful and well known retailer, Marshall Field, popularized: «The customer is always right». Of course, if a customer abuses the guarantee by returning several times a small unused portion of a package or a well cleaned steak bone — she may be «invited» to take her patronage elsewhere. In a short time any such abuse is stopped. The advantages of the «money-back guarantee» policy far outweigh the disadvantages in the opinion of food retailers in America.

The growth of the food industry in America to become the largest industry in the world, totaling in 1959, \$69.3 billion was not accidental. This spectacular progress and accomplishment in the U. S. A. could not have occurred without the simultaneous development of a mass production system and a mass distribution system. These two systems are interlocking and mutually supporting. Mass production means high-volume, low-cost production and mass distribution means high-volume, low-cost distribution. Mass distribution is essential if people are to gain the benefits of mass production on farms and in processing plants.

Supermarkets, now accounting for 70 % of retail food stores sales in the U. S. A., didn't put the small grocery stores out of business. Consumers did that. Just as people chose automobiles in preference to the horse and buggy, or electricity over candlelight, they expressed their preference through patronage for bright, clean supermarkets over the small, dimly lit corner grocery stores. The supermarket system of merchandising is based on self service, with large variety, giving consumers the freedom of choice. This change in the pattern of consumer patronage shows clearly that consumers are able to express their free choice among the retail outlets. It also proves that opportunity to grow and to succeed is wide open for men with ability, imagination and determination to serve customers, to earn and hold the public confidence.

Now there are several essential elements to the operation of the self service system which are significant to this congress. One of course is the improved types of meat animals developed especially for eating quality. Second is scientific feeding of the animals to produce quality meat. Third, is the establishment of modern packing houses, where animals are slaughtered and prepared for consumption under sanitary and scientific conditions. An essential part of this processing operation is the retention, use and sale of all parts of the animal. Many uses have been developed in our country as you no doubt have discussed during this congress. Suffice it to mention here that farmers, feeders, processors and retailers can and properly should work together to develop economic uses and efficient methods that will help reduce costs of edible meat to consumers and at the same time improve the quality of the meat product.

The research facilities of the United States Dept. of Agriculture have contributed much to the scientific progress and the quality control of meat

in our country. Improvement of breeds and types of meat animals to produce the flavorful lean meat preferred by consumers in our country also is an example of cooperation between government, producers, meat packers and retailers.

Packers or slaughterers cannot very well give a money back guarantee to the retailer on every steak, roast, or chop if his customer is unhappy after her family has eaten the meat. Therefore, the retailer must have uniform, dependable quality so he can guarantee customer satisfaction. And packers know if they expect to get repeat orders, they must deliver meat the retailer can guarantee with confidence. The cutting and trimming of meat, removing excess fat and bone from retail cuts are examples of packer-retailer cooperation for the consumer benefit. All of this joint effort increases sales, profit and consumption of meat.

With a changing distribution system from little stores to large supermarkets, loyal customers are essential. A premium is therefore placed on individuality and personality in each market to attract and hold customers. Distinctive meat, is one way in which the food retailer builds individuality. Beef is the largest single item in supermarket sales. Meat represents about 25 % on the average, of sales in supermarkets and beef is almost one-half of all meat sales. Poultry now represents about 12 % of meat department dollar sales and almost 15 % on a tonnage basis. Poultry is a relatively low priced meat item. The growth of poultry production in the United States is worthy of special comment. In the ten post war years broiler production increased over 15 % annually (over the preceding year) — from 293 million birds in 1946 to 1.3 billion in 1956. Turkey production increased in the same ten years from 41 million to 76 million annually — about 90 %. This is a tribute to scientific feeding and business management in the poultry industry.

It also presented a challenge to retailers to develop consumer demand and acceptance. It will be evident, therefore, that self-service supermarkets are vitally interested in feeding methods that will produce uniform quality «good eating» beef and poultry — and all other meats — that will satisfy their customers day after day. The retailer tries to have trim of cuts, dependable quality, and variety in his meat department which will attract and hold customers. The smart, successful retailer learns what customers in each area want and tries especially to satisfy them.

No one segment of the industry, grower, feeder, farmer, packer, processor or distributor — can long fulfill its function, its very reason for existence of serving the consumer better at a profit, without the support and cooperation of the others. Each is dependent on the other. Food on the farm is not food on the table. The producer needs the processor and the distributor. The packer depends on the producer for supply and the retailer for sales to consumers. The distributor must have the producer and packer to supply products needed and wanted by his customers. It must be recognized that the consumer is «boss» to whom all members of the team must cater.

Now these you know are basic aims in retailer relations with the public everywhere. But what about the significance of this new system of food distribution which broadens the scope and opportunity for service. It is well known that countless millions of people in the world are hungry. This makes them susceptible to promises of a fuller life. Without an improved system of distribution, yes, and without education and — ultimately — the



means of creating capital, the economy of the countries in process of development faces a long hard struggle to fulfill the wants and needs of the people.

Modern distribution which offers promise of widespread usefulness is based on the self-service principle. Hence, one of the most important dates in the history of distribution was 1916 when the first self-service food store was opened in the U. S. A. It now is estimated that about 90 % of grocery sales in the United States are by self-service. And the sales of perishable food products such as meat, fruits, vegetables, and dairy products are continuing rapidly to be converted to self-service methods with an estimated 50 % to 60 % sold through self-service today.

Why was — and is — self-service important to mass distribution? First, because of its effect on cost. Second, because it stimulated competition setting in motion forces which paved the way toward other efficiencies in handling food and accelerated the rise of the supermarket.

Amonf other influences of self-service which are equally important and far-reaching are:

1) The stimulating effect on the demand for food. Self-service, through its invitation to «impulse» purchases, had an impact on the American food standard of living. The freedom to touch, see, smell, and feel merchandise increases sales and, as a result, food consumption is increased. This broadens markets for farm food products and helps create additional jobs all along the line from farm to table. Larger sales also reduce costs and allow lower prices which, in turn, increase food purchasing power.

2) A revolution in packaging resulting in more sanitary, easily hanled products. The great development in the packaging and canning industries as we know them today was hastened by self-service. And improvements in standardization of quality and quantity of the products inside the packages became essential when self-service was introduced to obtain repeat sales. The package and the can had to become «silent salesmen» for their products to compete for consumer attention in self-service.

3) Inauguration of one-price merchandise with the price marked on each item and the same price to all customers.

Aside from its purely economic effects in terms of cost of distributing food and increasing food consumption, self-service is a form of economic democracy. The consumer has free, unhampered choice. She can vote for the store she prefers to shop in, the different food items she wants, and for brands of her own choice. She is on her own, with no one to influence her or interfere with her freedom of choice. By her patronage, she has demonstrated that she likes self-service.

The food distribution system has, as does all sucessful economic activity, the objective of better satisfying consumer wants and needs. Progress in the food industry of a nation is measured by two things — the percentage of national income spent for food and the minutes or hours of working time required to buy specific items in a food basket. By both these measures the United States food industry rates high. About 22 percent of our disposable income goes for food as compared with about 50 percent in many European countries and as hig as 75 percent in some of the Middle Eastern and Asiatic countries.

At the same time, the proportion of work-time required to buy a given quantity or quality of food in the United States has been falling continuously

(in real prices), so that food has kept step with, and frequently exceeded, developments in efficiency in other parts of the economy. For example, recent study revealed that the average factory worker of 1958 had gained almost an hour of purchasing power for a typical food basket over the work-time required in 1952.

Savings to consumers become even more dramatic when the dollar savings through the reduction in distribution costs is shown. In 1933, food chain margins were 24.6 percent of the sales dollar. In 1959, these margins were down to 20.5 percent, a saving of many millions in consumer expenditures. This can be converted to increased purchasing power for a wide variety of products, services, amusements, and culture.

Americans are justifiably proud of their standard of living, and the food industry is proud of having contributed substantially in creating the abundance, convenience and variety which we enjoy for so little effort. It appears that the principle might be stated: The extent and speed of development of the civilization of a nation depends greatly upon its ability to feed its people economically in terms of national effort.

The supermarket is recognized today as a typical American institution. Kings, queens, prime ministers, potentates, as well as visitors in all walks of life and strata of society are eager to see an American supermarket. This is one American idea that the people of all nations like and appear to be willing to adopt without envy or resentment.

Forward looking foods distributors of many countries have visited the United States in the past ten years under the sponsorship of the Marshall Plan agencies — by various names — to study and learn about this remarkable system of food distribution. At the request of our government, we have for over 10 years, organized study trips of about six weeks duration during which food distributors from abroad learn and observe food processing and distribution in all phases. Younger people study under the State Department Exchange-Visitor Program, earning while they learn as apprentices for one year in food chain companies. Most of these young people return to executive positions in family businesses in their home countries.

More spectacular have been the «Supermarket USA» exhibits in cooperation with the Departments of State, Commerce and the Foreign Agricultural Service of the Department of Agriculture. Ten thousand square foot, completely stocked supermarkets attracted well over a million and a half visitors to International Trade fairs in Rome, Italy, Zagreb, Yugoslavia and Barcelona, Spain. Over six-hundred American manufacturers cooperated with each of these projects providing the equipment, fixtures, and merchandise to equip and stock the markets. Upon completion of all exhibits, the equipment was sold to local enterprises which are using it to operate markets. In each country, these markets are forming the basis for rapid expansion of the self-service system of distribution.

The potential effect on the standard of living and on the way of life of people in many countries is almost beyond conception. His Holiness, Pope Pius XII, recognized the principle of self-service in a special message and commented favorably on it as an example of consumer participation and possible saving on the price of food, as well as a moral influence on the people. Over 100 self-service markets have opened in Italy and potential growth is tremendous.



President Tito of Yugoslavia, on visiting the «Supermarket USA» exhibit, said: «we must have this for our people». Now the people have it, operating as a going concern in Yugoslavia. About 60 such markets are planned there. The head of the Federal Chamber of Commerce in Yugoslavia pointed out that women could save four hours a day in shopping time alone. «It is conceivable», he said, «that speeding up the tempo of shopping could influence the tempo of men and women in their work, thus ultimately increasing productivity in the country».

In the past ten years, since U. S. Government Marshall Plan agencies, the Foreign Agricultural Service, U. S. Department of Agriculture, Office of International Trade Fairs of the Department of Commerce with the cooperation of the American food industry have been active in exchanging information and experience, some 20,000 self-service food stores have been opened in over 50 countries outside of the United States. Germany, Switzerland, Denmark and England are leaders. We understand that about 150 self-service markets have opened in Spain during the past year, since the «Supermarket USA» was exhibited in the Barcelona Trade Fair.

President Eisenhower said recently that «change is indeed the way of life and of progress». Change in the food distribution system in the United States in little more than forty years has been revolutionary. There is reason to believe that other countries now are experiencing a similar 'change'. That change truly means progress—progress to a higher standard of living for consumers; progress to broader opportunities, more prestige, and larger pay-checks for employees; progress to greater efficiency and stronger businesses for competitors; progress to increase good will, better understanding and more international trade for the citizens of many nations.

History shows that the system may triumph which offers people in developing countries hope for food, clothing, and better living standards. To those whose yearning for the basic necessities of life has been unsatisfied for centuries, modern, efficient production, processing and distribution which have grown out of and contributed to our free enterprise system, could provide the ray of hope they are seeking. American businessmen and government officials unselfishly and sincerely want to share their knowledge and experience, if it is desired, and if it can improve the living standards of others and advance the cause of peace.

## DISCUSSION

MODERATOR. Thank you very much, Dr. Logan for your highly interesting paper on the important role played by supermarkets. Any questions, please?

*Dr. Romagosa (Spain).* It has been said that American mixed feeds manufacturers sell their products to their customers on credit. Now I would like to ask two questions. First: What is the current interest on American money which allows American feed manufacturers to finance the large economic value of their investments? Second: What are the preventive measures adopted by the American industry to cover themselves against a disease outbreak? Is there any reinsurance fund administered by the U. S. Department of Agriculture or a cooperative fund established by the manufacturer themselves?

*Dr. Andreas (U. S.).* Generally, in our country, feed manufacturers lend

their own money to the breeders. There are some government credits for farmers, but they are very limited: I guess about 90 % of credits given the farmers for feed acquisition are financed by feed manufacturing companies, at an interest. There are no reinsurance systems or programs, although in some cases there are small companies which negotiate what we call an insurance against catastrophes: they pay a normal premium and, were their credit losses too high the insurance company would help them. But I repeat there is very little insurance in this area.

*Dr. Mascort* (Spain). A question for Mr. Logan. I recently read in a Spanish newspaper that there is in England a consumers' association the purpose of which is to recommend their members the products which they should or should not buy. Do you think this system can motivate the manufacturers to improve their products? Is there any such association in the United States?

*Dr. Logan* (U. S.). Yes sir. We have several organizations of this kind. Some of them are quite effective and they contribute to improved quality and lowered prices. However, I do think that the supermarket system is the best for the consumer. You buy a product and if you do not like it, you just do not come back to the store, as you have plenty of stores and plenty of products to choose from. Whatever the system, any quality control system must be very carefully developed. Anyway, the customer is the best judge of a product's quality. We have for example an information service in New York City, run by an agricultural organization, which supplies data and information to the farmer about the best products, qualities and prices in the American markets. This is a very good system, but in the last instance, it is the consumer who says the last word.

MODERATOR. Any more questions? Well, then we will finish our session. Now, for the next Panel, Professor Cordiez, of Belgium, who will act as Moderator for Panel VI. Thank you very much.



## PANEL VI

MODERATOR (*Dr. Cordiez* — Belgium). First of all I would like to extend my congratulations to the organizers of the present Conference for incorporating pathology problems to nutrition genetics problems and to feed merchandising activities. It is absolutely necessary to introduce good quality feeds and to raise healthy animals in order to transform these feeds into good meats, as all these efforts could become useless for reasons of pathological phenomena of collective character. For this reason, animal diseases represent a very important element in animal productivity. Therefore, we must extend our knowledge of prophylaxis. For this purpose, we have here highly qualified scientists, one of whom, Dr. Pomeroy (U. S.) will now read a report on «Diseases of Poultry in the United States».

### DISEASES OF POULTRY IN THE UNITED STATES

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During the past ten years poultry production has changed rather dramatically and these changes have resulted in the intensification of certain disease problems. These problems and economic losses to the industry are emphasized by the condemnations revealed under the mandatory federal poultry meat inspection that was initiated in January, 1959. A high percentage of the loss was due to infections of the respiratory tract.

The serious diseases encountered in the production of broiler chickens are as follows:

- 1) Respiratory Diseases
  - a) Newcastle disease
  - b) Infectious bronchitis
  - c) Laryngotracheitis
  - d) Chronic respiratory disease
- 2) Infectious synovitis
- 3) Avian leukosis complex
- 4) Coccidiosis

In poultry-raised for egg production in addition to the above problems, there are 1) Infectious vibrionic hepatitis 2) Avian encephalomyelitis 3) Fowl cholera 4) Salmonellosis 5) Avian tuberculosis.

The turkey industry has changed from a seasonal production to year around programs in many areas. Three types of programs are practiced: 1) broiler-fryer turkey production 2) turkeys raised to maturity 3) breeder flocks.

The major disease problems encountered in turkey production are: 1) Infectious sinusitis and related air sac infection 2) Ornithosis 3) Salmonellosis 4) Bluecomb disease (transmissible enteritis) 5) Entero-hepatitis 6) Coccidiosis 7) Erysipelas 8) Infectious synovitis 9) Fowl Cholera.

The diseases listed above involving chicken and turkey production cover the major problems, but the list does not cover all the infectious or parasitic problems associated with the poultry industry.

## 1) RESPIRATORY DISEASES OF CHICKENS

### a) *Newcastle Disease.*

Newcastle disease continues as one of the major problems facing the poultry industry. In the broiler production areas periodic upsurges of the disease are encountered from year to year. There is no single explanation for the cause of these breaks, but the following may be contributing factors: 1) the lack of vaccination against the disease 2) inadequacy of vaccine strains to immunize against some field strains 3) failure to vaccinate according to the recommended procedure.

The mass methods of vaccination are used commonly to immunize broiler and replace laying flocks. The application of the vaccine in the water is the most common procedure, but spray and dust applications are used. The B<sub>1</sub> and La Sota strains are used by commercial manufactures. Vaccines prepared with the wing web strains (Roakin and Mass MK107) are used in very limited areas. There is considerable interest in the development of a killed virus vaccine for Newcastle disease and the results appear promising (1) (2) (3).

In addition to the studies with inactivated vaccines, studies with a virulent living-tissue culture propagated NDV vaccine have been reported. Both types of vaccine produced protection against signs of disease and death following challenge but the tissue culture vaccine protected layers against a drop in egg production whereas the inactivated vaccine gave less protection (4) (5).

A recent report (6) indicated that a strain of NDV as been isolated from



laying flocks that had been previously vaccinated with B<sub>1</sub> type of vaccine and showed marked drop in egg production and respiratory signs. In experimental trials the B<sub>1</sub> strain did not protect against this strain. Other reports indicate the failure of B<sub>1</sub> vaccine to protect under field conditions.

Under laboratory conditions the infectious bronchitis vaccine (IB) given simultaneously with ND vaccine interferes with the response of the ND vaccine (7). It has been a very common practice under field conditions to use a combination vaccine of IB and ND viruses.

#### b) *Infectious Bronchitis*

Infectious bronchitis virus appears to be widely distributed in the U. S. In broiler production it causes a retardation of rate of gain and market condition. In laying flocks it causes serious drop in egg production and a loss of interior and exterior egg quality. There is evidence that there may be more than one serological type of IBV (8) (9). This may account for vaccination «breaks» under field conditions.

#### c) *Laryngotracheitis*

The problem of infectious laryngotracheitis in broiler raising areas was recognized as a distinct problem with the isolation and identification of strains producing mild respiratory signs. The strains of low pathogenicity protected against the virulent and vaccine strains of the virus (10) (11).

#### d) *Chronic Respiratory Disease*

The CRD complex under field conditions usually involves several etiological agents. *Mycoplasma gallinarum* is recognized as the cause of specific uncomplicated chronic respiratory disease. It is egg transmitted. Considerable progress has been made in elucidating this problem. Recent reports (12) (13) indicate the existence of different serological types. Some are associated with mild lesions involving the air sacs only and in the case of turkeys do not cause involvement of the sinuses. Laboratory procedures for the isolation and identification of *Mycoplasma gallinarum* are not considered reliable unless several procedures are used such as embryonated eggs, media, and bird inoculation. The use of serological tests in the detection and evaluation of flock infections has been extensively studied but unfortunately antigens are not available from commercial sources.

Under field conditions the CRD complex may involve several diseases and environmental factors. The PPLO infection is the common factor. It may develop into an active infection by vaccination reaction or natural infection of infectious bronchitis, Newcastle disease or laryngotracheitis, alone or in combination. In many field cases *E. coli* further complicates the problem by producing a septicemia resulting in an exudative process involving the air sacs, heart, liver and other visceral organs. Environmental factors such as chilling, over crowding, and poor ventilation all add to the problem resulting in excessive losses.

The treatment of field outbreaks with antibiotics, furazolidone and potentiated feeding programs results in some improvement, but the basic disease problem is still present. The ultimate solution of the CRD problem and the complicating secondary and mixed infections will depend on cooperative efforts on the part of all segments of the poultry industry.

## 2) INFECTIOUS SYNOVITIS

A recent report (14) indicated that a PPLO was the causative agent of infectious synovitis. This agent requires more exacting nutritional requirements than other pathogenic strains. Studies (15) on immunity indicated that there was very little following natural infection and none with formalized vaccines. Several workers (16) (17) (18) (19) have evaluated the use of tetracyclines and other antibiotics and drugs under experimental conditions. The activity of the tetracyclines potentiated by low calcium diets and terephthalic acid have been extensively studied. Some strains of the agent are susceptible to low level, 50 gm./ton of feed of chlortetracycline whereas others require 200 gm./ton.

Since the causative agent has been identified more specifically, the studies on transmission may provide more adequate control measures.

## 3) AVIAN LEUKOSIS COMPLEX

This problem continues to be one of the major diseases affecting poultry production and has caused concern in broiler production. Burmester (20) has recently reviewed the studies on avian leucosis complex. There appears to be no new measures to effectively control this perplexing problem under practical conditions.

## 4) COCCIDIOSIS

Coccidiosis continues to be one of the major causes for loss to the poultry industry. The use of coccidiostats in broiler and growing rations has been widely used and are helpful in reducing the incidence of coccidiosis (21). The development of programs on immunization against avian coccidia has received considerable attention (22) (23). In replacement laying flocks there may be a place for such a program but in chicken broiler production, it is questionable.

## 5) INFECTIOUS HEPATITIS

Vibronic avian infectious hepatitis continues to be a problem. The diagnosis of vibronic hepatitis is based on the isolation of the causative agent (24). The isolation of the agent in five to seven day old embryonating chicken eggs is superior to cultural procedures. Various antibiotics and chemotherapeutic agents have been used in the treatment of this disease. The tetracyclines and particularly furazolidone have shown promise in the control of the disease (25).



## 6) AVIAN ENCEPHALOMYELITIS

A Recent report (26) indicates the widespread distribution of the virus throughout Canada and U. S. In laying flocks a temporary drop in production without other visible symptoms may be noted. Egg transmission appears to be limited to the period of active infection in the laying flock, and the disease may be observed in the chicks during this period. With the year around production of hatching eggs, outbreaks of the disease in chicks may be encountered at any time. The control of the disease (AE) by immunization of young chickens has received considerable attention. Killed and live virus vaccines have been employed experimentally and various routes of administration have been studied (27) (28) (29) (30) (31).

## 7) FOWL CHOLERA

Although fowl cholera has not occurred in epizootic form, it is found in most of the poultry producing areas particularly the Midwest. The variable pathogenic nature of different isolates of *Pasteurella multocida* must be considered in a control program. In the turkey producing areas acute fowl cholera may be confused with erysipelas on the basis of gross pathological changes. Recent studies with different killed *Pasteurella multocida* vaccines gave very encouraging results (32).

## 8) SALMONELLOSIS

### a) *Pullorum disease*

The voluntary programs of the National Poultry and Turkey Improvement Plans continue to show progress in the reduction of the incidence of pullorum disease and fowl typhoid. 63.8 percent of the hatcheries and 75.8 percent of the hatching egg capacity in the country are under the NPIP (33). There has been comparable progress in the turkey industry. There is considerable interest in developing an eradication program on the state level. In 1959, 40 states reported that pullorum disease had been diagnosed by official laboratories and 19 states encountered fowl typhoid. Eleven states have a compulsory pullorum control program involving chicken and turkey breeding flocks.

### b) *Paratyphoid Infections*

The paratyphoid and related arizona infections continue to be a problem in the turkey raising areas and occasionally in chickens. *S. typhi-murium* is the most common sero type encountered, but many other serotypes are isolated from fowl. The contamination of feed ingredients with salmonellas presents a serious problem in attaining the goal of eradication of pullorum disease, fowl typhoid and paratyphoid infections.

## 9) AVIAN TUBERCULOSIS

The disease continues to be encountered in the North Central States where poultry production is largely confined to farm raised flocks. It is not a problem on commercial poultry farms that follow adequate management programs. The problem of avian tuberculosis in fowl is emphasized by the reports of the Poultry Inspection Service, of the U. S. D. A. that supervises the mandatory poultry inspection program.

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MODERATOR. We want to express our gratitude to Dr. Pomeroy for his excellent report on diseases of poultry in the United States. I think it would be best now to have Dr. Cuckler read his report on the coccidiostats problem, and then have a discussion session on poultry pathology.

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7  
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## COCCIDIOSTATS FOR POULTRY

ASHTON C. CUCKLER and WALTER M. OTT

Merck Institute for Therapeutic Research Rahway, N. J., U. S. A.

Coccidiostat has come to mean a chemical compound used in the feed, or in the drinking water, for suppression of the parasites that cause coccidiosis. Coccidiosis is a protozoan disease widely distributed and affecting many species of animals. In chickens and turkeys the intestinal tract is affected. In chickens the most pathogenic and economically important species of coccidia are *Eimeria tenella* and *E. necatrix*, and the less pathogenic species are *E. acervulina*, *E. maxima* and *E. brunetti*.

The continuous feeding of a coccidiostat for the control of coccidiosis is generally recognized as an essential feature in successful commercial production of broilers and flock replacement chickens. Sulfaquinoxaline was the first compound successfully used as a coccidiostat (1), and its development and use for this purpose permitted the poultry industry to expand enormously without the limitations and hazards of uncontrolled coccidiosis. Following the introduction of sulfaquinoxaline, many other chemicals have been discovered and developed which were also effective for coccidiosis.

A tabulation of coccidiostats that have been or are being used is given in Table 1. This listing shows the structural formula, the chemical name, the generic name and the trade name (and manufacturer), where applicable. Many of the compounds are used alone as coccidiostats. On the other hand, such products as Bifuran, Trithiadol, Polystat and Unistat contain 2 or more chemical compounds as active ingredients. In general the commercial form of the coccidiostat is a premix in an appropriate carrier to make a suitable product for feed manufacturing use.

The primary purpose in using a coccidiostat is to control the morbidity and mortality from coccidiosis. However, these compounds differ considerably in effectiveness against the various species of coccidia. Peterson (2) recently made a study of the comparative effectiveness of 8 coccidiostats against *E. tenella* and *E. necatrix*, and McLoughlin and Chester (3) have compared the effectiveness of 6 coccidiostats against *E. tenella*. On the basis of this and other published information on controlled comparisons under laboratory conditions, estimates of the comparative effectiveness of 11 coccidiostats against 5 species of coccidia are indicated in Table 2. Of course, these estimates are approximations since no study covered all compounds for all species, or even for any one species of coccidia. Naturally, one can not translate these estimates directly into field performance, since many other factors must also be taken into consideration (4, 5).



TABLE I

STRUCTURES AND CHEMICAL, GENERIC AND TRADE NAMES OF COCCIDIOSTATS  
R DESIGNATES TRADE NAME; NAME OF MANUFACTURER IS GIVEN IN PARENTHESIS

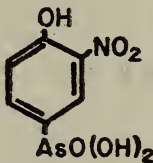
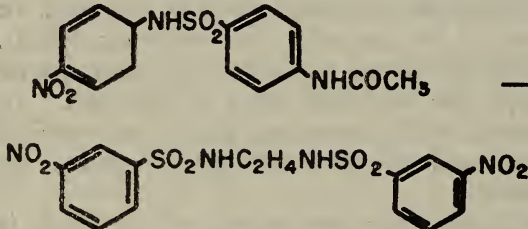
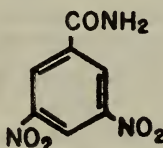
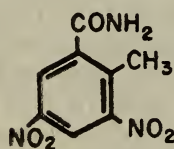
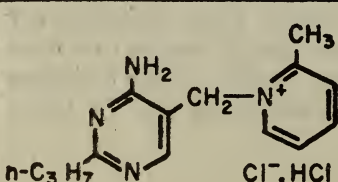
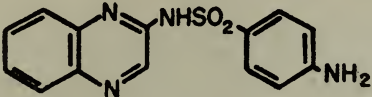
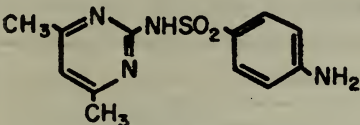
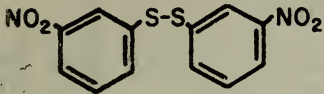
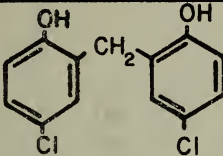
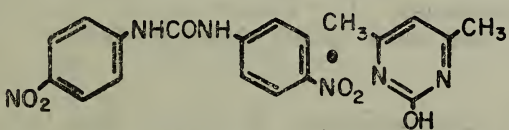
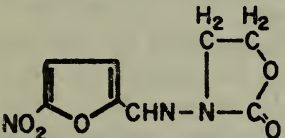
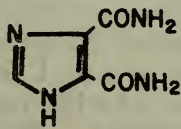
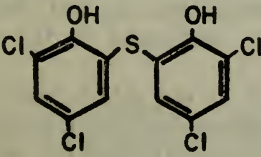
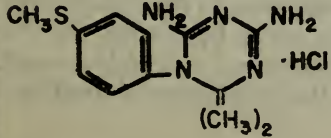
|                                                                                                                   |                                                                                                        |                                           |                            |
|-------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|-------------------------------------------|----------------------------|
|                                  | arsenosobenzene.                                                                                       | Arzene® (American Cyanamid)               | Polystat® (Dr. Salsbury's) |
|                                  | 3-nitro-4-hydroxyphenylarsonic acid.<br>3-Nitro®                                                       | acetyl-(p-nitrophenyl)-<br>sulfanilamide. |                            |
|                                  | dinitrodiphenylsulfonyl-<br>ethylene diamine.                                                          |                                           |                            |
| $(C_4H_9)_2Sn[O_2C(CH_2)_{10}CH_3]_2$                                                                             | dibutyltin dilaurate.                                                                                  |                                           |                            |
| <p>(above)</p> <p>(above)</p>  | 3-nitro-4-hydroxyphenylarsonic acid.<br>acetyl-(p-nitrophenyl) sulfanilamide.<br>3,5-dinitrobenzamide. |                                           | Unistat®                   |
|                                                                                                                   |                                                                                                        |                                           |                            |
|                                | 3,5-dinitro-o-tolamide.<br>zoalene.                                                                    | Zoamix® (Dow)                             |                            |
|                                | 1-(4-amino-2-n-propyl-5-<br>-pyrimidinylmethyl)-2-picolinium<br>chloride hydrochloride.<br>amprolium.  | Amprol® (Merck)                           |                            |

TABLE I (Cont'd.)

|                                                                                     |                                                                                                                            |
|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
|    | $N'$ -(2-quinoxaliny)sulfanilamide.<br>sulfaquinoxaline. S.Q. ® (Merck)                                                    |
|    | $N'$ -(4,6-dimethyl-2-pyrimidinyl)sulfanilamide.<br>sulfamethazine. Sulmet ® (American Cyanamid)                           |
|    | bis(m-nitrophenyl)disulfide.<br>nitrophenide. Megasul ® (American Nitrophenide-20 ® Cyanamid)                              |
|    | 2,2'-methylenebis (4-chlorophenol).<br>dichlorophene. Parabis ® (Dow)                                                      |
|    | 4,4'-dinitrocarbanilide<br>complexed with<br>2-hydroxy-4,6-dimethylpyrimidine.<br>nicarbazin. Nicarb ® (Merck)             |
|   | 5-nitro-2-furaldehyde semicarbazone.<br>nitrofurazone. nfz ®                                                               |
|  | 3-(5-nitro-2-furfurylidene amino)-<br>-2-oxazolidone.<br>furazolidone. nf180 ® (Hess & Clark)                              |
|  | 4,5-imidazoledicarboxamide.<br>glycarbylamide. Glycamide ® (Merck)                                                         |
|  | 2,2'-thiobis (4,6-dichlorophenol).<br>bithionol.                                                                           |
|  | 4,6-diamino-1-(4-methylmercaptophenyl)-<br>-1,2-dihydro-2,2-dimethyl-1,3,5-triazine<br>hydrochloride.<br>methiotriazamine. |

Bifuran ®

Trihiadol ® (Sterwin)



TABLE II

COMPARATIVE EFFECTIVENESS OF COCCIDIOSTATS AT RECOMMENDED USE-LEVELS IN CHICKEN FEED

| Coccidiostat     | <i>E. tenella</i> | <i>E. necatrix</i> | <i>E. acervulina</i> | <i>E. maxima</i> | <i>E. brunetti</i> |
|------------------|-------------------|--------------------|----------------------|------------------|--------------------|
| Sulfaquinoxaline | +++ (3,6)         | ++ (6,7)           | +++ (9,11)           | +++ (9)          |                    |
| Nitrophenide     | +++ (6)           | ++ (6,7)           | ++ (11)              |                  |                    |
| Bifuran          | ++ (2,3)          | ++ (2,7)           |                      |                  |                    |
| Nicarbazin       | ++++ (2,3,9,10)   | ++++ (2,9,10)      | +++ (9,10)           | ++ (9,10)        | ++++ (10)          |
| Glycarbylamide   | ++++ (2,3,9)      | ++++ (2,9)         | ++ (9)               | 0 (9)            | ++++ (11)          |
| Trithiadol       | ++ (2,3)          | ++ (2)             |                      |                  |                    |
| Arsenosobenzene  | ++++ (2)          | ++ (2)             |                      |                  |                    |
| Polystat         | ++++ (2)          | ++ (2)             |                      |                  |                    |
| Unistat          | ++++ (2,8)        | ++ (2,8)           | +++ (8)              |                  |                    |
| Zoalene          | ++++ (2,10)       | ++++ (2,10)        | ++ (10)              | ++ (10)          | ++ (10)            |
| Amprolium        | ++++ (10)         | ++++ (10)          | ++ (10)              | ++ (10)          | ++ (10)            |

++++ = complete or nearly complete protection, ++ = moderate activity, 0 = no activity. References are given in parentheses; blank spaces indicate absence of data.

Although the development of drug resistance in coccidia may limit the usefulness of a coccidiostat, little information is available on this matter. Resistance of *E. tenella* and *E. acervulina* to sulfaquinoxaline has been reported to develop slowly, whereas little or no increase in resistance to nicarbazin was found (4). Studies with amprolium (10) showed that little or no development of resistance to this coccidiostat occurred in *E. tenella*, thus indicating that amprolium may be similar to nicarbazin in this respect.

The comparative tolerance of chicks to coccidiostats can be conveniently investigated in short-term feeding tests using graded concentrations above the recommended use-level. Results of such studies with 4 coccidiostats (12, 13, 14, 15) are combined in Fig. 1. Here, 100 % weight gain corresponds to the mean gain of the non-medicated control birds. The sloping curves represent the mean weight gains of birds fed corresponding concentrations of the indicated coccidiostats. The maximum tolerated dietary concentration (for growth) is the intercept between the sloping curve and the horizontal control line. In general neither stimulation nor depression in growth occurred with concentrations below these maximum tolerated dietary concentrations. The small margins between the maximum tolerated dietary concentrations and the use-levels of sulfaquinoxaline and of nicarbazin can be contrasted to the wider margins with amprolium and glycarbylamide.

Information on the concentration of coccidiostat in the edible tissues of poultry is required in order to determine an appropriate withdrawal time prior to slaughter or whether a tolerance limitation must be established for a tissue residue. Review of the literature on tissue concentrations (16) shows data on 4 coccidiostats in muscle (Fig. 2) and 5 coccidiostats in liver (Fig. 3). With the recently introduced coccidiostats in this group no detectable residues remained in the tissues by the third day after discontinuance of feeding the

coccidiostat. Therefore, with the observance of recommended, practical withdrawal periods, poultry meat should contain no residues of these coccidiostats as determined by assay methods sensitive to about 0.1 part per million. On the other hand, tolerances have recently been established for zoalene and its metabolite at concentrations of 2 ppm. in chicken muscle and fat and 6 ppm. in chicken liver and kidney (17).

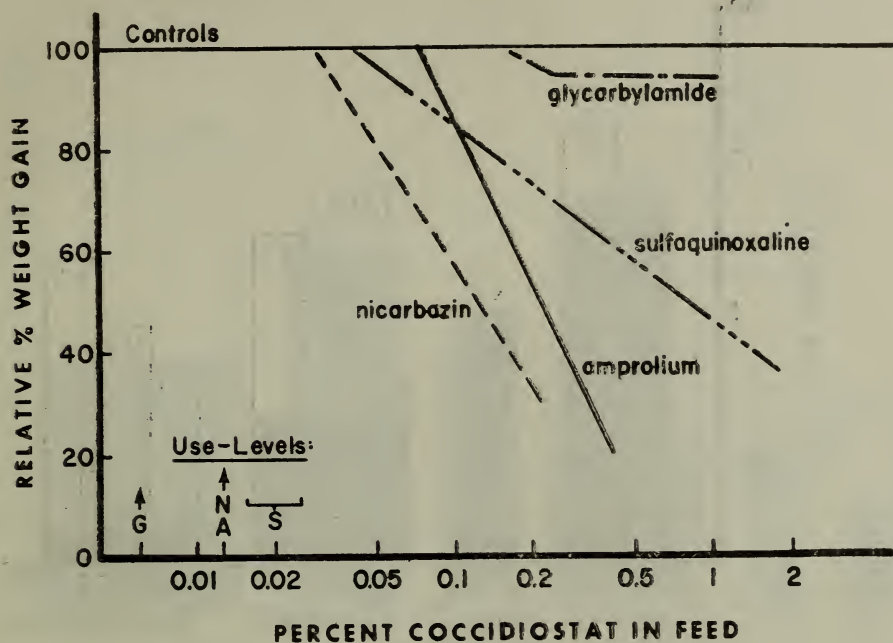


FIG. 1.—Comparative tolerance of chicks to coccidiostats in 3-4 week feeding tests in battery brooders.

The practical application and usefulness of coccidiostats also involve consideration of many other characteristics such as tolerance by other species of animals, pharmacodynamic effects, assayability, stability, compatibility with other feed ingredients, effect on incidence of coccidiosis in field usage, etc. (5). Very little comparative information appears to be available along these lines, and consequently a review of these factors would probably be too limited to be useful.

## SUMMARY

Coccidiostats for poultry were listed, showing structural formulas and chemical, generic and trade names. Published information on efficacy and safety was reviewed. Estimates of the comparative effectiveness of 11 coccidiostats against 5 species of coccidia were tabulated. The comparative tolerance of chicks to 4 coccidiostats was presented. Information on tissue residues was summarized.



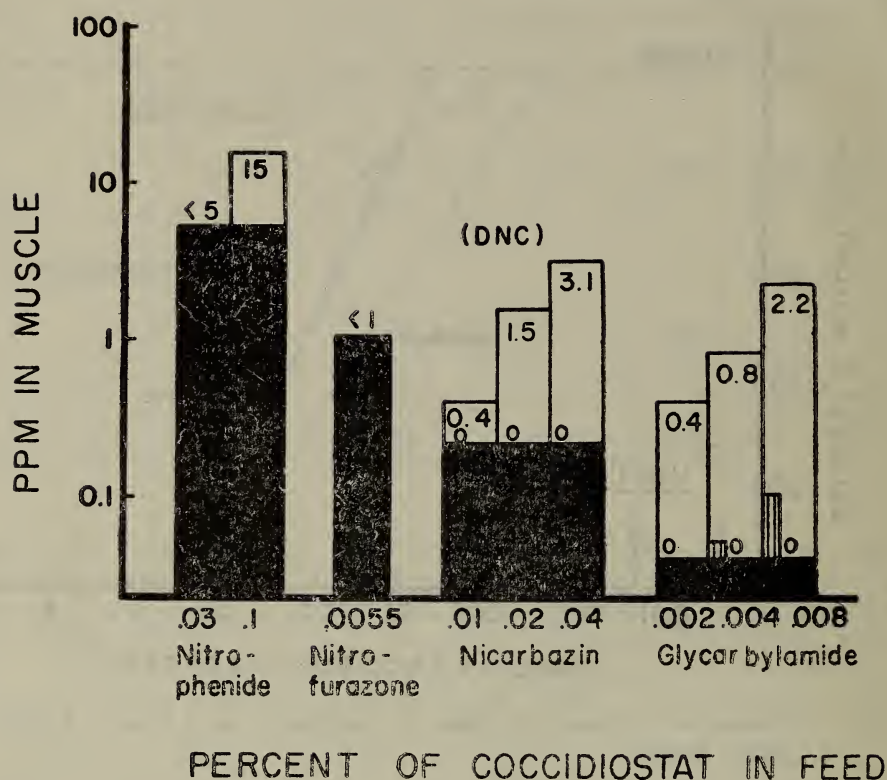


FIG. 2.—Concentrations of coccidiostats in chicken muscle. Number and height of white bar show concentration during feeding of indicated percent in feed. Height of inside bars indicates concentrations at 1, 2 and 3 days (from left to right) after withdrawal of coccidiostats from feed. Height of black bar indicates limit of sensitivity of assay method.

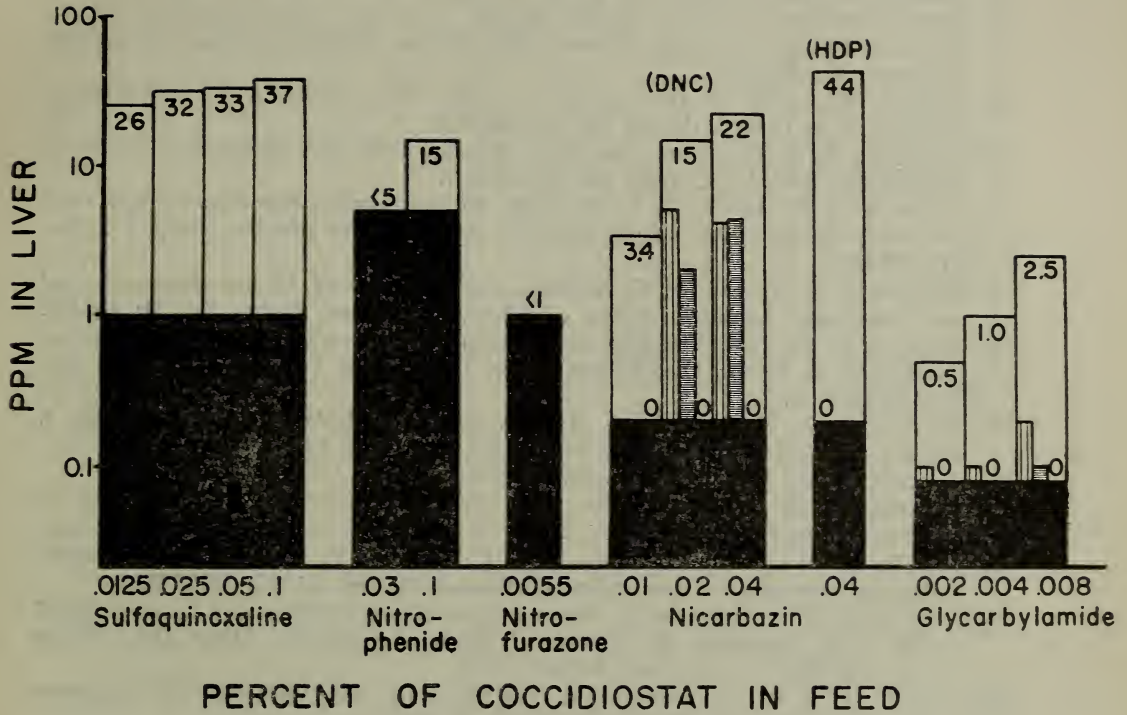


FIG. 3.—Concentrations of coccidiostats in liver of chickens during and after feeding of indicated percent in feed. (See Fig 2 for explanation).



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MODERATOR. We thank Dr. Cuckler for his masterly lesson on a problem of capital importance in poultry husbandry. Now we will proceed with the questions and answers session.

## DISCUSSION

*Dr. Rubio* (Spain). My congratulations to Dr. Cuckler for his interesting report. One question, please. Sometimes it is not possible to withdraw coccidiostat treated feed three days before slaughter. At least, this is what happens in Spain rather often. Could this have any detrimental effect on human health?

*Dr. Cuckler* (U. S.). The recommended procedure is to withdraw it a given period before slaughter. The general procedure in our country is to follow the withdrawal period established by the manufacturers. Concentration

levels for most coccidiostats are so low, that human consumption of tissues containing such coccidiostats level is not likely to produce any detrimental effects on public health.

MODERATOR. Any more questions please?

*Dr. de Juana* (Spain). I would like Dr. Cuckler to tell us whether he has considered for his research work an antibiotic which is becoming rather popular in France, called «fragmicetin».

*Dr. Cuckler* (U. S.). We have not used this product in our experiments.

*Dr. Beherens* (Germany). I would like to ask Dr. Cuckler whether he can tell us something about coccidiostat performance.

*Dr. Cuckler* (U. S.). You mean how do coccidiostats act? I must say that I do not really know. Our experiences dealt with eleven different chemical compounds, all of them having in more or less degree some coccidiostatic activity. I can say that most of the compounds studied affected the development of the second generation. How? That I cannot answer.

*Dr. Palacios Remondo* (Spain). We have had the opportunity to check different lots of poults bred under practical conditions, the feeds used were supplemented with nicarbazin at normal levels as indicated by the manufacturers. The poults were treated with therapeutical drugs of the sulfaquinoxaline type. The response was not a positive one, and coccidiosis progressed as if no treatment had been given, which does not happen generally in the cases when no coccidiostats were added to the feed. I would like an answer from Dr. Cuckler, regarding this question.

*Dr. Cuckler* (U. S.). If I understand your question properly, it seems to me that we have two possibilities here. First, coccidiosis was not the real problem. Second, the additives were not used in the right concentration. There is a third possibility, that of a drug resistance developed in coccidia. As I have indicated in my report, there is the risk in some cases of development of drug resistance in coccidia. There are, therefore, three ways which may explain the problem, but I cannot give any better explanation.

*Dr. Scheys* (Belgium). I would like to ask whether the coccidiostat itself may have a detrimental influence on animal health, independently from his beneficial effect as a medicine against coccidiosis. Do you think it would be convenient to use some vitamins in conjunction with the coccidiostat in order to correct a detrimental effect on the animal's health? For example, blood coagulation may or may not be detrimentally affected by the use of coccidiostats, in which case this might be corrected by supplying vitamin K. What is your opinion?

*Dr. Cuckler* (U. S.). Yes, I think vitamin K could be beneficial in that case.

*Dr. Scheys* (Belgium). Thank you very much. I will repeat now my second question. It refers to coccidiostats association. I ask whether integrated or associated coccidiostats can reduce the amount of each one of them with the same efficiency, for example, with an association of nitrofurazone and nicarbazin. In other words: Can we use several coccidiostats at the same time for fighting coccidiosis? Would this result in a lower of each of the necessary coccidiostats?

*Dr. Cuckler* (U. S.). Coccidiostats have an inhibitory effect on poultry growth.

*Dr. Scheys* (Belgium). Can several coccidiostats be associated for fighting



coccidiosis? Can we use a combination of two or three coccidiostats as a preventive measure against coccidiosis in order to improve effectiveness?

*Dr. Cuckler* (U. S.). It might well be that a combination of several coccidiostats proves no better than one coccidiostat. Sometimes it might be better, while in other cases this will depend upon the type of combination used. We see sometimes that available commercial products include a combination of two or more chemical products for the purpose of obtaining the desired coccidiostat activity. On the basis of such products it is unnecessary to combine them in any way for maximum activity. I think we cannot deal with this subject in general terms.

*Dr. Cid* (Spain). I would like to emphasize the importance of *Dr. Scheys'* questions, which have brought out a very interesting point, regarding coccidiostats association. Personally, I have observed cases of avitaminosis B2 when using commercial levels of nicarbazin after which we had to use nitrofurazone for treating those cases not responding to nicarbazin treatment. From this we can consider that nicarbazin-nitrofurazone combination could correct such cases.

MODERATOR. Before going into the subject of ruminant pathology, I want to extend my sincere congratulations to Mesrss. Pomeroy and Cuckler for their masterly dissertations. Now, *Dr. Link* will deal with the subject: «Diseases of Ruminants in the United States».

## DISEASES OF RUMINANTS IN THE UNITED STATES

R. P. LINK

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A disease of cattle recognized in California in 1953 was subsequently designated infectious bovine rhinotracheitis (12, 19). Although first recognized as a distinct disease in dairy cattle it later became a disease of great economic importance in beef cattle.

In lactating cows, the first evidence of infection was a sudden, drastic drop in milk production, ceasing completely in two or three days. Initially morbidity was usually low with less than ten per cent of the animals becoming affected. However, additional cases developed almost every day for three or four weeks. Temperatures of affected animals ranged from 102° to 108° F. with most of them about 150° F. Most animals refused to eat and ceased ruminating. They salivated and occasionally would grind their teeth. The mucosa of the nares was inflamed and there was a mucopurulent nasal discharge. Respirations were shallow and rapid, and a short explosive cough soon developed (8).

The muzzle and external nares were hyperemic and encrusted with dried mucopurulent exudate and desquamated epithelial cells.

Internally the entire nasal mucosa was swollen and congested, and variable quantities of exudate were present. In severe cases mucopurulent and fibrinous exudate was deposited on the surface of the mucosa and occluded

much of the meatuses. When the exudate was removed the mucosa usually was intact but in some areas contained foci of ulceration from necrosis. The ventral turbinates were affected more severely than the dorsal parts of the nasal cavity.

The paranasal sinuses showed changes similar to those of the nose. In early stages the mucosa of the pharynx was hiperemic and hemorrhagic. In advance stages the surface was covered with mucopurulent and fibrinous exudate. The trachea contained multiple foci which were hyperemic. Mucus was excessive in amount and the submucosa was edematous. In advanced stages there was a mucopurulent-fibrinous bloody exudate covering the hyperemic, edematous mucosa. Fatal cases showed extension of the severe tracheitis into bronchii and bronchiolos and development of bronchopneumonia.

Multiple erosions were occasionally present in the abomasum. The abomasum and intestine showed acute catarrhal inflammation in some cases.

### INFECTIOUS PUSTULAR VAGINITIS

A vesicular venereal disease has been frequently reported among cattle in Central Europe (4) and occasionally in North America. First report from Europe was in 1886 (1) and from North America in 1895 (9).

Clinical signs and symptoms described were similar in all reports. There was a reddening of the mucosa of the vulva with dark-red pin-point areas that soon grew to nodules, vesicles, and pustules. These were 2 to 6 mm. in diameter and were water clear or yellow-red. In some cases the pustules coalesced to form a yellowish-white fibrinous membrane. The membrane soon became detached leaving an exposed ulcerated area. The vulva usually was swollen and the animals exhibited evidence of pain by arching the back, switching the tail and urinating frequently. A small amount of exudate was discharged from the vulva throughout the course of the disease. There was some fever and impairment of milk production in lactating cows.

Bulls were reported as affected and lesions similar to those seen in the vulva were found on the penis and in the prepuce. There appeared to be no age susceptibility since cases have been reported in calves 5 weeks of age and in all intermediate ages up to 7 years. Repeated infections seemed to occur in some animals.

There is no uniform evidence indicating that the infection causes sterility.

Transmission occurs readily during coitus. Several investigators successfully transmitted the disease experimentally. Reisinger and Reimann (18) first succeeded in reproducing the disease with a bacteria-free filtrate, thereby establishing the character of the specific causal agent. The disease was successfully transmitted by McIntyre in 1954. Isolation and characterization of the virus causing the disease was reported in 1956.

Although these two entities differ greatly in location of the tissues affected by the disease, the causative agents appeared to be identical (8). Studies on infectious bovine rhinotracheitis (IBR) and infectious pustular vulvovaginitis (IPV) virus showed marked similarity of tissue culture features. Both viruses were cytopathogenic, attained equivalent virus titers, and produced intranuclear inclusion bodies in tissue culture bovine kidney cells. A comparison



of effects of the two viruses in cattle showed that each virus immunized against itself and the other virus. In reciprocal immunization tests, serums from cattle recovered from infection with either virus neutralized both viruses and similar serum antibody titers were found. These features indicated that IBR virus and IPV virus are the same (6). It has been postulated that point of entrance of the virus into the body determines the character of the disease produced.

### VIRUS DIARRHEA

An acute infectious, contagious disease of cattle was recognized in New York State in 1946 (15). Clinically the disease was a gastro-enteritis with severe diarrhea. Initially there was fever with temperatures of 105°-108° F. Usually ulcers developed in the mouth and nose and on the muzzle of the severely affected animals 2 to 4 days after onset of clinical signs. A mucopurulent nasal exudate also developed in the severely affected animals.

This highly contagious disease was characterized by high morbidity, fever, nasal discharge, ulceration of muzzle, nose, lips, tongue and oral cavity. The disease was transmitted to susceptible cattle and was later designated virus diarrhea.

### MUCOSAL DISEASE

A somewhat similar disease was reported from Iowa in 1953 (17). This entity was named mucosal disease because the tissue changes were confined principally to the lamina epithelia and mucosa of the alimentary canal. Virus diarrhea—Indiana was reported in 1954 (16). This disease was similar clinically to virus diarrhea—New York but was thought to differ somewhat clinically and immunologically. Subsequent work has established a single virus as cause of the three originally recognized diseases.

### VIBRIOSIS IN EWES

Abortifacient infection of ewes by organisms designated as *Vibrio fetus* has been described as possessing biochemical characteristics distinguishing it from morphologically identical but nonpathogenic isolates. These characteristics include the ability of pathogenic cultures to produce catalase and inability to produce hydrogen sulfide. The nonpathogenic isolates produce hydrogen sulfide but not catalase.

In 1959 two outbreaks of vibronic abortion were identified in Kentucky flocks (3). These flocks were 90 miles apart and there was no recognized means of infection spreading between the flocks. Cultures of vibrio species from the flocks were morphologically indistinguishable from isolates from four other outbreaks of vibriosis. They were found to be biochemically distinct from the four cultures. Cultures from the two flocks produced both catalase and hydrogen sulfide. These findings would question the reliability of biochemical tests for determining the disease-producing capability of *Vibrio fetus* isolates.

## INFECTIOUS POLYARTHRITIS IN SHEEP

An infectious polyarthritis of sheep has been described (13). Lameness, usually in one leg only was the initial sign of the disease. Often the affected leg was carried and no weight was born on it. Affected animals would assume various stances so as to remove weight from the diseased limb. Depression, fever, hyperpnea, and anorexia were observed in more severely affected animals.

A serofibrinous or fibrinous synovitis was a constant finding. When there was excessive fluid there usually was enlargement of the joint, extensive peri-articular edema, and pin point hemorrhages in the soft joint tissues and regional muscles.

A virus-like agent was isolated from fluid obtained from affected joints (14). The disease was reproduced in apparently healthy sheep when the agent was injected subcutaneously or intravenously. The infectious agent seemed to be related to the psittacosis-lymphogranuloma group. No confirmed reports are available regarding effect of therapy. However, in vitro the infectious agent is sensitive to terramycin and penicillin.

## BOVINE PAPULAR STOMATITIS

A disease of cattle which has been recognized in Europe for many decades has been diagnosed in the United States (5). This disease, bovine papular stomatitis, probably had existed in the U. S. for some time before it was recognized. This relatively mild viral disease of calves is characterized by proliferative lesions in and around the mouth and nostrils without systemic signs of disease. The lesions resemble those of the early stages of foot-and-mouth disease, vesicular stomatitis and mucosal disease.

## WHITE MUSCLE DISEASE

White muscle disease has been growing in importance among young animals in the U. S. This has been particularly true in the western states. Vitamin E therapy has been recommended in treatment of this condition but it has not been a universally successful therapy. However, it is effective in preventing the disease when administered prophylactically.

Recent work has been directed toward use of selenium with or without vitamin E as prophylactic or corrective therapy for this condition (10). Selenium appears to possess the ability to prevent development of this condition. However, in grazing animals it has not always been convenient to supplement the rations for cows and ewes. It has been demonstrated that by injecting subcutaneously, barium selenate suspended in oil, into ewes fed hay from ranches known to have histories of white muscle disease, no cases of this disease developed in their lambs. This approach may provide a convenient way of preventing development of this disease in cattle and sheep maintained on premises where this apparent deficiency disease occurs.



## AVITAMINOSIS A IN CATTLE

There appears recently to be an increasing incidence of vitamin A deficiency in fattening cattle fed rations similar to those used for many years without previous history of this condition. Good quality yellow corn has been recognized as a good source of cryptoxanthine, the precursor for vitamin A. Corn kept in storage is known to lose some of this substance. However, in a number of herds of fattening cattle in Illinois vitamin A deficiency has been recognized both from clinical signs and chemical assay of blood specimens (7). It is not known what factors are responsible for development of this condition. The corn being fed, has not, in any case been old corn.

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MODERATOR. Thank you very much, Dr. Link. Now, we will listen to Dr. Sacchi (Italy) on «Mastitis Control».

## MASTITIS CONTROL AND ADVANCES IN THERAPY

BY

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Having been close to the problems of mastitis diagnosis and therapy both in Europe and the United States, we have had the opportunity of making observations on certain phases of mastitis as a complex disease entity. We are reporting here the experience gained in conducting the State of Maryland Mastitis Control Program (1).

The points that will be subjects of this discussion are: diagnostic procedures, types of udder infection, eradication of *Streptococcus agalactiae*, hemolytic staphylococci infection, gram-negative infection, milk gains, therapy, a new approach to therapy.

## DIAGNOSTIC PROCEDURES

Milk samples were collected in sterile vials, the milk was cultured as soon as possible after collection without previous incubation period. The laboratory method employed was the blood-agar plate method as suggested by the New York State Mastitis Control Program. Readings were done at 24 and 48 hours of incubation at 37° C. After 24 hours of incubation the macroscopic appearance of colonies was observed. Streptococci colonies were subject to CAMP test (2). Staphylococci colonies were not subject to any particular



laboratory tests and we limited ourselves to making observations on their ability to hemolyze bovine blood of known low staphylococcal antihemotoxin content. Gram-negative growths were seeded in Kligler iron agar. After 48 hours gram-negative bacteria were grossly identified as follows:— *Pseudomonas aeruginosa*: by appearance of pigmentation, odor, hemolysis, alkaline reaction on Kligler iron agar. «*Pseudomonas type*»: by acid butt, alkaline slant, little or no gas in Kligler iron agar. *Coliforms*: by production of acid and gas in Kligler iron agar. *Proteus species*: by acid butt, alkaline slant, production of hydrogen sulfide in Kligler iron agar.

## TYPES OF UDDER INFECTIONS

The following data and considerations refer to 602 complete surveys conducted in 114 herds averaging 34 cows, where not less than three and up to 17 surveys took place in each herd. Laboratory work involved the bacteriologic examination of 86,252 milk samples. Quarter infection as found in the first survey of these 114 herds was: *Hemolytic staphylococci* 39 %; *Streptococcus agalactiae* 32 %; streptococci other than *Streptococcus agalactiae* 25 %. These offenders or facultative offenders accounted for 96 % of the total infection, the remaining 4 % infection were attributed to gram-negative rods. However, these infections, although accounting for but 4 % of the total constituted a serious problem for 30 of 114 herds.

## ERADICATION OF STREPTOCOCCUS AGALACTIAE

*Streptococcus agalactiae* was identified in 87 of the 114 herds and its eradication was undertaken in 73 herds. After considerable effort (see table I) 33 herds were made *Streptococcus agalactiae* free and 26 reached a point very close to complete freedom of this infection. It is our opinion that the elimination of *Streptococcus agalactiae* should always be attempted because it is relatively simple to obtain, and because it gives a certain degree of freedom from clinical mastitis and it brings about sizeable milk production increases. If eliminated from the mammary glands *Streptococcus agalactiae* will not tend to reappear since it does not survive in the environment for a long period of time. This type of infection is readily susceptible to antibiotic therapy, in fact we have never isolated directly from one udder a strain of *Streptococcus agalactiae* that could be called antibiotic resistant.

TABLE I

PATTERN OF DISAPPEARANCE OF STREPTOCOCCUS AGALACTIAE INFECTION, EXPRESSED IN PERCENTAGE OF QUARTERS, IN THE 33 HERDS THAT WERE MADE AGALACTIAE FREE

| Herd<br>no. | Survey no. |     |     |     |      |     |      |     |   |
|-------------|------------|-----|-----|-----|------|-----|------|-----|---|
|             | 1          | 2   | 3   | 4   | 5    | 6   | 7    | 8   | 9 |
| 9           | 12         | 2.6 | 2.3 | 0   | 0    | 0   | 0    | 0   | 0 |
| 3           | 20         | 5.0 | 3.6 | 7.6 | 4.3  | 4.8 | 2.5  | 0   | 0 |
| 6           | 5.4        | 1.4 | 0.6 | 0   | 0    | 0   | 0.9* | 0   | 0 |
| 22          | 17         | 5.0 | 0.9 | 0   | 0    | 0   | 0    | 0   | 0 |
| 51          | 14         | 5.8 | 5.4 | 3.8 | 7.2  | 2.1 | 0    | 0   | 0 |
| 20          | 19         | 1.3 | 0.8 | 0.7 | 0.6  | 5.0 | 0    | 0   | 0 |
| 4           | 11         | 0.6 | 1.9 | 0   | 0    | 0   | 1.0* | 2.1 | 0 |
| 58          | 9.2        | 7.2 | 0.7 | 5.0 | 3.6  | 0.5 | 0    | 0   |   |
| 40          | 17         | 9.8 | 6.0 | 4.5 | 0    | 0   |      |     |   |
| 10          | 4.0        | 2.6 | 0   | 0   | 0    | 0   |      |     |   |
| 15          | 12         | 2.5 | 0   | 0   | 0    | 0   |      |     |   |
| 124         | 15         | 4.7 | 2.2 | 1.4 | 0    | 0   |      |     |   |
| 139         | 4.2        | 0   | 0   | 0   | 3.6* | 0   |      |     |   |
| 39          | 6.0        | 0.8 | 0   | 0   | 0    |     |      |     |   |
| 29          | 13         | 3.2 | 0.6 | 0.6 | 0    |     |      |     |   |
| 21          | 21         | 0   | 0   | 0   |      |     |      |     |   |
| 54          | 12         | 1.0 | 0   | 0   |      |     |      |     |   |
| 42          | 5.5        | 0   | 0   | 0   |      |     |      |     |   |
| 39          | 13         | 0.7 | 0.6 | 0   |      |     |      |     |   |
| 38          | 6.3        | 0   | 0   | 0   |      |     |      |     |   |
| 24          | 6.3        | 2.8 | 0   | 0   |      |     |      |     |   |
| 59          | 9.4        | 0   | 0   | 0   |      |     |      |     |   |
| 16          | 6.5        | 0   | 0   |     |      |     |      |     |   |
| 127         | 11         | 1.3 | 0   |     |      |     |      |     |   |
| 110         | 2.4        | 0   | 0   |     |      |     |      |     |   |
| 107         | 10         | 0   | 0   |     |      |     |      |     |   |
| 132         | 21         | 0   | 0   |     |      |     |      |     |   |
| 17          | 5.0        | 0.8 | 0   |     |      |     |      |     |   |
| 134         | 15         | 0   | 0   |     |      |     |      |     |   |
| 30          | 11         | 1.7 | 0   |     |      |     |      |     |   |
| 105         | 5.7        | 2.1 | 0   |     |      |     |      |     |   |
| 104         | 22         | 2.7 | 0   |     |      |     |      |     |   |
| 141         | 25         | 11* | 0   |     |      |     |      |     |   |

\* Addition of newly purchased mature animals to the herd.

## HEMOLYTIC STAPHYLOCOCCI INFECTION

Because the majority of the quarters infected with these organisms were yielding normal milk, and in consideration of the scarce response to treatment, eradication was attempted for experimental purposes only in three large herds where incidence of clinical mastitis was high and where initial percentages of quarter infection were respectively 44, 17 and 24 %. We failed to



succeed in the eradication and the three herds exhibited, as seen in the last survey the following percentages of infected quarters: 12, 8.6, and 12 %. In our opinion *Hemolytic staphylococci* eradication even if possible for experimental purposes is impractical because of the difficulties in achieving it, and the impossibility of maintaining it. If eradication from udders were reached other foci of infection within the same animals, more conceivably uterus and skin would in time cause *Hemolytic staphylococci* reappearance in the mammary gland.

## GRAM-NEGATIVE INFECTIONS

Aside from the readily recognisable *Pseudomonas aeruginosa* we labelled as «coliforms» organisms that could really have been *Escherichia coli* or *Aerobacter aerogenes* and we classified as «*Pseudomonas* type», a seemingly never ending collection of nameless udder pathogens. In order to obtain additional information on «*Pseudomonas* types» a number of cultures were investigated and they could further be identified as *Aerobacter aerogenes* — like paracolon, *Escherichia* — like paracolon, and *Proteus* species.

It was observed that presence of *Proteus* species or *Serratia marcescens* may or may not have a pathologic significance while, as observed by other authors (3), (4) the presence of *Pseudomonas aeruginosa* should always be considered pathologic.

## MILK GAINS

It was possible to substantiate with Dairy Herd Improvement Association records on hand or, where these were not available by computation of milk check stubs that 61 of the 114 herds had substantially increased their milk production. In 12 herds milk gains could be defined as remarkable having registered increases ranging from 60 to 100 %. In another group comprising nine herds production increased anywhere 20 and 60 %. Gains from 10 to 18 % were shown by 42 herds. As a general rule striking milk gains were reached in *Streptococcus agalactiae* infected herds where the initial percentage of infection and physical abnormalities of milk were high. They were seen more often in common rather than in pure bred herds, and more often in dealing with a mediocre but willing dairy man rather than with an experienced one. Whenever we had the opportunity of correcting critical situations that had not yet developed in an irreversible manner and where the full potentialities of the animals could be restored, sizeable milk production increases were always in evidence.

## THERAPY

The preferred method of treatment used in our experimental herds was, of course, that of antibiotic therapy. Antibiotics were administered by the intramammary route after the evening milking. In our efforts to eliminate *Streptococcus agalactiae* infections Penicillin or Terramycin were used with equally satisfactory results. Penicillin and dihydrostreptomycin in combination were utilized for the treatment of *Hemolytic staphylococci* infections while the

OINTMENT OR POMADE TYPE CONVENTIONAL MASTITIS PREPARATION



FIG. 1.—Radiograph taken immediately after treatment. Ointment vehicle does not mix with milk. Some still remains in teat canal.



FIG. 2.—Radiograph taken 1 hour after administration. Dark masses still show poor ability of this type preparation to dissolve.



FIG. 3.—Radiograph taken 4 hours after administration. Globes of ointment are still present, medication is not being released.



SPECIAL TERRAMYCIN AQUEOUS TYPE MASTITIS PREPARATION

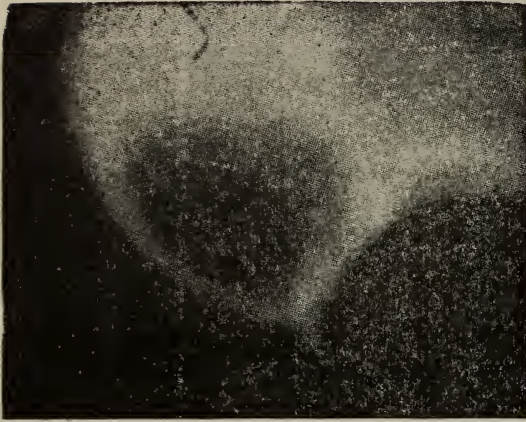


FIG. 4.—Radiograph taken immediately after treatment. Note fast even dispersion upward throughout the udder.



FIG. 5.—Radiograph taken 1 hour after treatment. As milk is secreted the aqueous formula continues to blend with the milk.

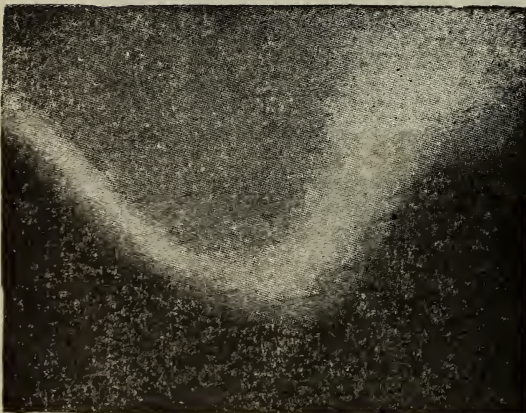


FIG. 6.—Radiograph taken 4 hours after treatment. Dispersion is complete, all diseased tissue comes in contact with antibiotic agent.

most successful treatment for the difficult cases of gram-negative infections was found to be a combination of Terramycin and Polymyxin B.

In the light of recent research (5), (6) the tests of antibiotic sensitivity of mastitis causing bacteria were recognised as valuable means of selecting the most suitable antibiotic agents to insure highest efficacy. Tablets or discs containing a small amount of antibiotic are placed on inseminated plates. Results are evaluated observing presence or absence of a zone of inhibition around each tablet. However, the size of the zone is not very important, that is, an antibiotic giving a wide zone of inhibition is not necessarily more effective clinically than another showing a smaller inhibition zone. Sensitivity tests have shown that the tetracyclines, streptomycin and penicillin appeared to be the most consistently effective drugs.

### A NEW APPROACH TO THERAPY

In the past, for reasons of antibiotic instability, the prepared mastitis products consisted of a mixture or suspension of the antibiotic in a petrolatum ointment or oil base. Such products have several disadvantages in that they only give a low antibiotic concentration in the milk, the limiting factor in these cases being the slow diffusion of the action drug from the petrolatum or oil phase to the aqueous milk phase. This results in longer milk out times (7) and the resulting lower antibiotic milk concentrations are not as effective in treatment of the disease as higher antibiotic concentrations would be. Many experimenters (8) (9) (10) have reported disadvantages using mastitis products where the antibiotic was in an ointment in oil base.

In a recent report an oxytetracycline mastitis product that is highly soluble in milk has been studied (11). The distribution characteristics of this soluble product in the udder were studied by radiographic technique giving *in vivo* evidence of the pattern of distribution of the antibiotic after administration into the lactating udder.

Two types of mastitis preparations were used in these experiments. The conventional ointment vehicle (see Fig. 1, 2 and 3) and the special aqueous solution vehicle (see Fig. 4, 5 and 6). Radiographic examinations of the quarters of mamary gland were conducted immediately after infusion, one hour and four hours after infusion by placing the portable X-Ray machine at a right angle to the long axis of the animal.

It is apparent from these radiographic examinations that the special aqueous solution vehicle obtained a much faster and greater diffusion entering into immediate contact with all the milk and milk secreting tissue. On the contrary the ointment or pomade type vehicle showed a tendency to float in a few large sized non-dissolving clumps that would remain captive in the lower portion of the udder without showing the desirable property of expanding evenly throughout the quarter and attaining only partial milk distribution.

Confirming evidence is shown in cross sections of udders of lactating cows sacrificed at various time periods after intramammary infusion of dyed products. The milk then shows diferent distribution characteristics. Clinical trials have confirmed the superior efficacy associated with the more favorable drug distribution. The uniform distribution also facilitates early milk out of the antibiotic from the udder (7), a practical problem presently confronting our Public Health & Regulatory Authorities.



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MODERATOR. Thank you very much, Dr. Sacchi. Now, we will listen to Professor Behrens on «Diseases of Swine in Europe, especially in West-Germany». This report will be followed by Dr. Kernkamp's communication on «Diseases of Swine in the United States».

## DISEASES OF SWINE IN EUROPE, ESPECIALLY IN WEST-GERMANY

BY

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The pig population of the world in 1959 was about 470 millions. The number of pigs kept in the different countries of the world are shown in Table I.

TABLE I

THE NUMBER OF PIGS KEPT IN 1959 IN THE DIFFERENT COUNTRIES OF THE WORLD

|                 |          |
|-----------------|----------|
| North — America | 80 mill. |
| South — America | 53 »     |
| West — Europe   | 58 »     |
| East — Europe   | 42 »     |
| Russia          | 49 »     |
| Africa          | 5 »      |
| Asia            | 183 »    |

The number of pigs kept in 1959 in the West-European countries are shown in Table II.

TABLE II

THE NUMBER OF PIGS KEPT IN 1959 IN THE WESTEUROPEAN COUNTRIES

|                 |            |
|-----------------|------------|
| West — Germany  | 14.8 mill. |
| France          | 8.3 »      |
| Denmark         | 6.1 »      |
| Great Britain   | 6.0 »      |
| Spain           | 4.0 »      |
| Italy           | 3.3 »      |
| Austria         | 2.8 »      |
| The Netherlands | 2.5 »      |
| Sweden          | 2.1 »      |
| Switzerland     | 1.2 »      |

The value of pig products in Great Britain is about £ 270 millions. In West-Germany 1950 the value of pig products was about DM 5,3 billions. This figure represents 24,3 % of the total agricultural production or 34,2 % of the total livestock production.

The losses in pig husbandry are considerable. A survey of the incidence and causes of mortality in pigs, carried out in England and Wales from 1956 to 1958 (1959) showed an average death-rate up to 8 weeks of age of 25,9 %. 80 % of the losses occurred before the end of the first week of life. Death in pigs over 2 months were estimated to be less than 2 %. The examinations made in West-Germany showed a death-rate up to 30-33 %. I think that in the other european countries the death-rate in pigs will vary from 25 to 30 or even 33 %. These figures tell us that in Great Britain the annual death-rate in piglets is about 3,5 million pigs and in west-Germany about 5,5 million pigs. To these fatal or direct losses we have to add the so-called non-fatal or indirect losses. They are caused by depressed growth rate, bad food conversion and reduced value of the carcass. It is very difficult to get correct figures about this non-fatal losses. Mostly these losses are underestimated.

I think that the total annual loss in pig husbandry is about 20 % of the value of pig products.

Which are the most important and economical pig diseases?

My account is mainly based on the situation in West-Germany. However I think that this will concern most of the West-European countries too.

## VIRUS PNEUMONIA OF PIGS

Virus pneumonia of pigs (Ferkelgrippe) is the world's most important swine disease. It is a contagious pneumonia of pigs, causing a mild clinical disease of long duration. It involves mainly the anterior lobes of the lungs. The causal agent is presumed to be a filtrable virus, based on the work by BETTS (1953). The virusinfection can be complicated by various secondary bacteria. Although recent work has shown that there might be different causes for infectious pneumonias in pigs, the majority of infectious pneumonias in pigs belong to virus pneumonia.



The losses caused by virus pneumonia are due not so much to mortality, which occurs mostly in young pigs, as to a reduction in the performance of the pigs. BETTS and coworkers (1955) have shown that pigs affected with virus pneumonia suffered a depression of growth rate and efficiency of food conversion of the order of 15-20 %. Furthermore it has to be stressed that the extent of the effect of virus pneumonia varies very much according to the conditions under which the pigs are kept and with different secondary infections. High morbidity and mortality are to be seen after introduction of the disease for the first time in fully susceptible herds. In chronic infected herds the losses become less presumable due to some immunity or increased resistance.

The control of virus pneumonia in pigs is very difficult. The infection does not build up a good immunity. Furthermore at the present time we have no method for active or passive immunization, nor is there any drug inclusive antibiotics which can prevent the infection or destroy the infectious agent in an animal under practical conditions. In infected herds losses can be decreased by good feeding together with antibiotics and keeping the pigs either especially during summertime in small pig huts or in a warm, dry stable, free from drafts.

The only way for eradicating virus pneumonia in infected herds has been shown by BETTS and coworkers (1955). By this method virus pneumonia of pig could be eradicated in a lot of herds in various countries, especially in Great Britain, Sweden and West-Germany.

### INFECTIOUS ATROPHIC RHINITIS

Infectious atrophic rhinitis (Schnüffelkrankheit) is a transmissible disease, characterized by atrophy of the nasal turbinates. This disease occurs in nearly all parts of the world where there is an extent pig husbandry. Before 1945 in Germany this disease was located chiefly in the eastern districts and nearly unknown in West-Germany. However since 1945 the disease does rapidly spread out in West-Germany.

There are several theories about the etiology of this disease. I think that to the present time we are able to stress that infectious atrophic rhinitis is caused by one or several primary infectious agents. In addition to the primary agents secondary bacteria and protozoa may invade and increase the clinical picture. I can't agree to the recent statement of BAKOS and coworkers (1960) that virus pneumonia of pigs and infectious atrophic rhinitis have the same primary agent. Pigs affected with infectious atrophic rhinitis suffer a considerable depression of growth rate and efficiency of food conversion, especially when the pigs are contemporary infected with virus pneumonia, kept under bad stable conditions and the disease does attack a formerly free herd.

The disease is mostly distributed by selling of external healthy pigs from infected herds. At the present time under practical conditions it is not possible to diagnose the disease in an external normal pig with sufficient accuracy. Therefore most of the herdowners observe the syndrome of infectious atrophic rhinitis in their pigs after the introduction of new breeding stock.

At the present time we have only one method for eradication the disease: the stamping out method. In every country the disease must become a noticeable disease and the government had to subsidize the losses caused by slaughtering the whole herd.

Infected herds that cannot be slaughtered, can diminish the losses by good stable conditions especially by a well balanced feeding.

## IRON DEFICIENCY IN BABY PIGS

Iron deficiency occurs only in baby pigs within the first 3-5 weeks of life. It is caused by the low iron content of the sow's milk. By the sow's milk the piglet gets only 10-15 % of the iron amount it needs for normal growth. Iron deficiency mostly occurs among piglets, kept indoor on concrete floors in small litters and sows which are good milkers.

At the present time the most distributed view about iron deficiency in pigs is that the piglets only needs iron for hemoglobin production and that the iron deficiency causes only the clinical syndrome called piglet or baby pig anemia. Yet recent research work has shown that in iron deficient animals the production of iron enzymes is decreased, which leads to disturbances in tissue metabolism (BEUTLER (1957)). Furthermore iron deficient animals are susceptible to infectious diseases (HEILMEYER et al. (1958)). The losses caused by iron deficiency are heavy. The sufficient supply with iron for piglets is most important for growing piglets. Iron deficiency can be prevented:

1.) by outdoor raising of the piglets so that they have access to natural ground,

2.) by soil (sod) placed in the farrowing stall, easily accessible to the baby pigs or

3.) by the application of iron to the piglets. Numberless different iron preparations have been tested during the last 10 years. At the present time the most efficient iron preparation is iron dextran which is to be injected in an amount of 100-150 mg Fe during the first week of life. Sometimes the dose is to be repeated about 3. weeks later. It is not possible to prevent iron deficiency in piglets by increasing the iron content in the sow's milk.

## VITAMIN A DEFICIENCY

Vitamin A deficiency occurs mostly in herds during the winter and spring months when the winter feed is deficient in Vitamin A or carotine. Symptoms of Vitamin A-deficiency are not to be seen in adult pigs, especially in sows, but mostly in piglets. This is based on the fact that the sow keeps for itself the amount of Vitamin A it needs for its own life. The syndrome of Vitamin A deficiency in piglets is small litter size in consequence of early embryonic mortality, stillbirth, stunted growth, susceptibility to infectious diseases, posterior paralyse and convulsions.

Vitamin A deficiency can easily be controlled by carotine rich feed, feeding of Vitamin A supplements or by Vitamin A injections in sows some days before mating and 4-6 weeks before farrowing. Furthermore the pig's feed has to content enough carotine or Vitamin A.



## SUDDEN DEATH IN WEANLING PIGS

In Germany a great number of pigs die within 2-3 weeks after weaning. The pigs are found already dead or just before death. Post mortem we always see a stomach heavily filled and extended with dry food and the symptoms of a disturbance of the heart and the systemic and pulmonary circulation. By this post mortem findings we think that these deaths are the consequence of the disturbance of the heart and the circulation caused by overfeeding and insufficient supply with water. We were able to prevent these losses by restricted feeding during the first 2-3 weeks after weaning and by the supply of enough water.

## EDEMA DISEASE IN PIGS

The edema disease in pigs first described by SHANKS (1938) in North Ireland, meanwhile has got a world-wide distribution. In some countries and especially in certain herds the losses are considerable. These losses occur mostly in an age of 2-4 months. During the last ten years very much research work has been done about the etiology of this disease. The result of this work is, that the edema disease is a toxemia, that the toxins are produced and located in the bowel content and that special strains of hemolytic *Escherichia coli* are involved in the production of the toxins. The factors that cause the production of the toxin are still unknown. My own observations seem to indicate, that sudden changings in feed stuffs, insufficient vitamin-, protein- and mineral supply might belong to these factors. Because the knowledge about the cause of the disease is still incomplete, effective treatment and preventive measures have not been developed. We found that very often losses could be stopped by restricted feeding and injections of Vitamin A and Prednisolon (20-50 mg). Preventive measures seem to be well balanced feed, sufficient supply with water, iron and vitamin A, D, E and avoiding of sudden changes in the feed stuffs.

## SARCOPTIC MANGE IN PIGS

Dirty skin disease is mostly attributed to vitamin-, protein or mineral deficiency and to unknown or indifferent internal disturbances. Our own recent work, done in West-Germany has shown that about 85 % of all pigs or herds affected with a rough hair coat suffer from sarcoptic mange. The typical clinical symptoms of sarcoptic mange are the dirty skin condition and the considerable itching which causes the animals to scratch and rub vigorously. These symptoms can be seen in pigs from the 4. week of life. The dirty skin conditions increase during the first months of life. Later they decrease especially when the pigs get a well balanced ration in adequate amounts, are kept under good stable conditions and are free from other chronic diseases.

On the contrary the clinical symptoms increase by bad feeding, unfortunate stable conditions and other chronic diseases (virus pneumonia, worm infestation a. o.). Losses by deaths are seldom, however considerable losses occur by depression of growth rate and efficiency of food conversion.

Sarcoptic mange in pigs can easily be diagnosed when the scrapings for demonstrating the mites are taken from the insides of the ear (BEHRENS (1956)).

The control of sarcoptic manges in swine is at the present time no more problem. The methods used commonly for the treatment are dipping, spraying and washing. The mange can be eradicated by through treatment with B H C, Lindane, Chlordane, Malathione a. o. The animals have to be treated twice within 12-14 days. It is very important, that all body surfaces, including the skin inside of the ears and the inside of the thighs be completely covered with the parasiticide. All animals in a herd must be treated.

### PARAKERATOSIS

Parakeratosis is a skin disease which can be mistaken with sarcoptic mange. The etiology of parakeratosis appears to be involved in a metabolic relationship of calcium and zinc. Beside the typical skin lesions (keratinous crusts on the surface of the skin) the feed intake of the affected pigs is markedly reduced already before the skin lesions are to be seen.

Parakeratosis is often mistaken with sarcoptic mange and contrary. Parakeratosis occurs chiefly by dry feeding. In the scrapings, taken from the inside of the ears, sarcoptic mange cannot be found.

Parakeratosis can easily be treated and prevented by adding zinc to the feed. Since this is known parakeratosis occurs very seldom.

### SWINE FEVER — HOG CHOLERA

Swine fever (Schweinepest) is no more a serious economic disease in Europe since effective immunization methods have been developed. In West-Germany active immunization is not allowed by law. We try to control swine fever by stamping out method together with restrictions in transport, selling a. s. o. During the last 10 years we could find that the clinical symptoms and the course of the enzootic have changed very much so that it is sometimes very difficult to diagnose swine fever.

### SWINE ERYSIPELAS

Swine erysipelas (Rotlauf), formerly a serious economic disease, is widespread in Europe. Since about 10-15 years swine erysipelas has become of less economic value. This has been reached not only by active immunization but chiefly by more effective drugs for treatment, especially antibiotics, and by better hygienic conditions the pigs are kept. During the last summer we have observed that because of neglecting active immunization causes a. subacute erysipelas and chronic erysipelas arthritis increased.



## WORM INFESTATION

The roundworm infestations play an important role in the economy of swine production. Recent examinations have shown that about 50 % of swine are infected with ascarids and/or nodular worms. In Germany swine are free from lungworms. Death losses caused by worm infestation occur seldom. The economic losses consist of lowered growth rate and depressed food conversion. Ascarid and nodular worm infestations can be controlled by the systematic application of effective anthelminty according to the biology of the worms together with hygienic measures. The most effective drug for ascarids is piperazine and for nodular worms phenothiazine.

## GASTRO-ENTERITIS-SYNDROME

Heavy economic losses are caused by the gastro-enteritis syndrome. This syndrome is characterized by diarrhoea, weight losses, stunted growth and deaths. The most important thing is to keep in mind is that diarrhoea is only a clinical symptom and not a diagnosis. Diarrhoea can be caused by infection with bacteria and viruses but very often it is a symptom of other diseases for instance pig anemia, vitamin A deficiency, swine fever, virus pneumonia, roundworm infestation. Furthermore we see diarrhoea caused by failure in feeding (efficient or spoiled feed) or insufficient supply with water. Instead of finding new strains of enteroviruses there is still a great number of gaps in our present knowledge about the gastroenteritis syndrome. Therefore intensive research work has to be done.

The most difficult work of the veterinarian is to find the cause of diarrhoea because all the measures for treatment and prevention depend on the diagnosis.

In a brief account I have mentioned and described some pig diseases, which cause considerable economic losses. I should like to stress, that fatal and non-fatal losses in pigs are not caused only by specific diseases or agents but by failures in feeding and housing too and that very often the specific diseases increase considerably by failures in feeding and housing.

By this fact losses in pig husbandry cannot be decreased alone by veterinarians but only in team work with the specialists in pig feeding and housing. Finally the swine producer is a very important factor. He will only be able to carry out the different methods for the control of pig diseases, when he is well educated about pig feeding, housing and the etiology and clinical symptoms of the most important pig diseases. In this way it might be possible to decrease the losses to the normal rate of about 10 % of the value of pig products. However there are a lot of problems about pig diseases still unsolved. Therefore a very important fact is that the expenditure for research in pig diseases, feeding and housing has to be increased. I should like to finish with the words BEVERIDGE said at the Annual Congress of the British Veterinary Association in Glasgow this year:

«Money put into research is invested, for the gains are permanent, but money into subsidies is spent and yields no dividends in future years.»

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## DISEASES OF SWINE IN THE UNITED STATES

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U. S. A.

With a swine population in the continental United States of approximately 55,000,000 head annually for the past several years (1), the probability that many different diseases occur among them is of a high order. The number of diseases that occur in swine in the United States would vary, no doubt, with the viewpoint of the persons preparing the list, as well as of those that come in contact with disease in swine and who have a real interest in their diseases.

Viewing disease from the standpoint of the veterinary clinician is somewhat different than from that of the veterinary pathologist. The clinician deals with a living abnormal subject; the pathologist, usually not until after death. The clinician even after using all the diagnostic armamentarium at his command (clinical thermometer, stethoscope, microscope, oscilloscope, x-rays, hematological, chemical, bacteriological, serological techniques, etc., etc.) is more limited in the examination of the patient than is the pathologist. In addition to the findings of the clinician, the pathologist has the benefit of a necropsy and various laboratory techniques before reaching a final diagnosis. These different but complementary approaches to the overall problem and study of disease in swine accounts for differences of opinion of some disorders and dysfunctions as being sufficiently distinctive and specific to be characteristic of a disease entity.

A «state of health» is defined as *that state of the body in which there is complete harmony with the environment, both internal and external*. From a practical point of view («sty-side» or «pen-side»), it is important to know

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when a pig or a drove of swine is considered normal and in a state of good health.

A pig in a good state of health is alert and active and each day consumes an amount of feed and water calculated to supply its need for maintenance, growth, and reproductive function — when being used for this purpose — and eliminates the body wastes regularly. Where an adequate diet is being supplied and the body weight and size and general physical condition bear a favorable relation to age, it can be assumed that a progressive increase in growth and weight has occurred and can be construed as a sign of good health. Also, when walking, running, or loping, a normal pig moves forward with a full stride. The skin of a normal, healthy pig is pliable and smooth, and the haircoat smooth and sleek. The body temperature when at rest or when moderately exercised may vary from 101.0 to 103.6° F. and the respiration is 18 to 30 per minute. Preferably, the pig should be free of anomalies and/or of inflicted injuries, although they may be of a nature so as not to interfere with the state of health.

Some latitude in the degree or extent of these «norms» should be allowed for the circumstances inherent to the mode of living (feeding, watering, shelter, pasture, etc.) on the premise when the state of health of the swine is being assessed. This must be left to the judgment of the attending veterinarian. Situations are not uncommon where swine considered to be in good health on one farm would be substandard on another farm.

In 1955 a Special Committee of the American Veterinary Medical Association submitted an outline or schema for classifying the diseases of animals on the basis of their cause (2). The outline is divided into several categories and each category into various subcategories. It is a commendable approach to the matter of listing and classifying diseases and aims at grouping together the diseases having similar causes. Following is a list of the categories and examples of the diseases that would be included in each.

1. Diseases due to prenatal influences: Such conditions as atresia ani, visceral herniations, cardiac septal defects, and vessel anomalies represent diseases that develop before birth and have an embryonal origin. Hairless pigs, resulting from an iodine deficiency in the diet of the parturient sow, develops in the unborn pig. Myoclonia congenita, also known as shivers, shakes, or trembles, develops while the pigs are still within the uterus. Its specific cause has not yet been established.

2. Diseases due to lower plant or animal organisms: Examples of diseases belonging in this category that are of bacterial origin are brucellosis, pasteurellosis, salmonellosis, swine erysipelas. Leptospirosis is a disease of spirochetal origin and coccidiosis, eperythrozoonosis and toxoplasmosis of protozoan origin. The viral diseases included in this category are hog cholera, swine pox, transmissible gastroenteritis, vesicular exanthema, and foot and mouth disease.

3. Diseases due to higher plant or animal organisms: This group includes diseases resulting from internal and external parasites, e. g., intestinal round worms, nodular worms, kidney worms, and lung worms, and also the mites that produce sarcoptic and demodectic mange.

4. Diseases due to intoxication: Poisoning that results from the ingestion of such metallic salts as arsenic, mercury, and selenium; or of the anthracene derivatives, such as coal tar and pitch; and the nephritic disorders resulting

from the excessive intake of sulfonamides and their derivatives are examples typical for this group. This category also takes in the anaphylactic, allergic, or hypersensitive conditions that result sometimes from the ingestion or the injection of «foreign» proteins. The skin diseases that result from the ingestion of certain photo-sensitizing agents, e. g., rape blister, clover intoxication, and food poisoning of undetermined type.

5. Diseases due to trauma and physical agents: In this category are such conditions as abrasions, contusions, crushing, avulsion, fractures resulting from sudden trauma or injury. Burns, scalds, and heat stroke, and injuries or tissue destruction due to electricity and x-ray are still other examples of ailments that would be included in this bracket of the classification.

6. Diseases that occur secondarily to circulatory disturbances: In this group are those conditions which develop because of some disorder or dysfunction of the heart and/or vascular system. An example is the pulmonary congestion and/or infarction that often results from the vegetative endocarditis which sometimes occurs in chronic swine erysipelas and in the valvular endocarditis due to streptococci.

7. Diseases that occur secondary to disturbances of innervation: Locomotory disturbances marked by lameness and/or paralysis that are the result of degenerative changes in nerves supplying some of the muscles of locomotion can be entered in this category. The stiff and «goose-stepping» gaits seen in riboflavin and pantothenic acid deficiencies are specific examples. The incoordination and progressive paralysis resulting from the meningo-encephalitis in pseudo-rabies is another example of a disease that fulfils the specifications of this classification.

8. Diseases due to or consisting of static mechanical abnormality of unknown cause: Examples of diseases included in this group would be such as characterized by abnormal vertebral curvatures (kyphosis, lordosis, scoliosis) and by intestinal dilation (megacolon), intestinal constriction (ileus) and by visceral displacements.

9. Diseases due to disorders of metabolism, growth, and nutrition: Hypoglycemia, hypoproteinemia, osteomalacia, nutritional anemia, and parakeratosis are typical of conditions of this order.

10. Neoplastic diseases (tumors): Disease of this kind is not very common in swine and is probably because the life of the vast majority of the swine (85 per cent or more) is terminated before they reach 12 months of age. In the words of Runnells (3), «They had not reached tumor age.» However, the tumors observed most frequently are embryonal nephromas and lymphoblastomas.

11. Diseases due to unknown or uncertain cause with structural reaction: Diseases in which one or another of the pathologic processes marked by degenerative, infiltrative, inflammatory, or proliferative changes occur for which a specific cause is not known are assigned to this category. Examples are fibrous interstitial nephritis, prolapsus recti, «post-anemic cachexia,» diarrhea («scours») in baby pigs.

12. Diseases due to unknown or uncertain cause with functional reaction: Disorders suitable for inclusion in this category are «repeat breeder» problems in females, the problem of «fetal absorption,» impotence and/or unwillingness to copulate in the boar.



It is recognized that some diseases listed might have been placed in categories other than the ones in which they are entered. If this has occurred, it is because the viewpoint of the writer with respect to the cause and nature of the disease, as they are known at this time, may be different from that of another cataloguer attempting to classify the diseases on the same basis. It is also recognized that when the etiology and nature of any of these diseases is more perfectly understood, the disease or diseases in question should be shifted to the category provided if that be necessary.

Most of the diseases in swine in the United States occur in all parts of the country where swine are husbanded. On the other hand, some of the diseases due to parasites are, for climatic reasons, restricted more or less to parts of the country that lie in the southern half of the temperate zone. The disease due to the kidney worm (*Stephanurus dentatus*) and that due to the thornhead worm (*Macracanthrocephalus hirudinaceus*) are examples.

From the viewpoint of soil type, there is some evidence to indicate that neutral and alkaline soils are favorable to the maintenance and development of *Bacillus anthracis*, the cause of anthrax (4). Further, it is strongly suspected that a relationship exists between soil type and the organism responsible for swine erysipelas. Soils rich in humus appear to be best suited to their development.

The fact that some diseases occur within relatively definite age periods in the lives of swine can be helpful toward recognizing their presence where pigs of a particular age group are sick. By the same token, it can be helpful differentiating between certain diseases.

There is much data to show and considerable reason to suspect that the first 24 to 36 hours of a pig's life is full of potential troubles. Most of the injuries and deaths that result from trauma inflicted by the dam occur in this period. The use of «farrowing crates» and «confining stalls» when the pigs are born and for seven days longer will reduce the loss from this cause considerably. This is also the period when entire litters of pigs may be born dead or weak to sows affected with leptospirosis, brucellosis, or whose rations during the gestation period were deficient in protein or in iodine. Myoclonia congenita is present when the pigs are born, as is also the «hairless pig» syndrome that is due to an iodine deficiency of the fetal pig. «Colibacillosis» and diarrhea(s) (scours) of undetermined origin are frequently present as early as the fifteenth hour from the time of birth and can be the cause of death in another 24 to 36 hours. Transmissible gastroenteritis (T. G. E.), while a disease that affects swine of all ages, is highly lethal to pigs under two weeks of age and is the reason why this is such an important disease. Infection with strains of T. G. E. virus of high virulence often causes pigs to become noticeably sick when only 16 to 18 hours old. An acute and highly fatal form of «uremia-toxemia» («UT»), (uremic poisoning, toxic milk sickness) occurs as early as the second or third day. Where this occurs, all the pigs in the litter are affected, but maybe only one litter in a herd of four or more sows and litters may be involved. Hypoglycemia is another disorder which often occurs in pigs under seven days of age.

In the second and third weeks, in addition to T. G. E., «U. T.», «pig scours», and hypoglycemia, one can expect to encounter such conditions as nutritional anemia (iron deficiency anemia — anemia of baby pigs), exudative

epidermitis (greasy pig disease), virus pneumonia of pigs (V. P. P.), subacute «U. T.,» pseudo-rabies, and acute swine erysipelas.

The period from the fourth to eighth or ninth week is a time when, as a rule, the early stages of certain diseases show up. The sneezing that is accompanied by the expulsion of bits of blood-tinged exudate or blood-tinged mucous is an early sign of atrophic rhinitis. This is also the period when the bulging facial distortions with ulcerating centers that characterize the granulomatous form of rhinitis («bullnose») occur. A very large proportion of the cases of edema disease occur in pigs of this age group, but it also occurs in pigs up to 16 or 18 weeks of age. Listeriosis, swine pox, and toxoplasmosis will often be seen in pigs under eight weeks and over three weeks of age. A «poor-doer» syndrome in pigs seven to ten-plus or minus-weeks of age has come to our attention, which, from certain preliminary studies, suggest a «post-anemic cachexia.»

After the seventh or eighth week, the relation of age to the occurrence of a particular disease is less definitive. Moreover, it is obvious that some diseases cited as occurring in the second or third and subsequent weeks, carry over into the older age group. If we were to place age limitations on the latter, it would be the ninth to the 18th week — a «feeder-pig» age. By the same rule, diseases cited as occurring more often in the «feeder-pig» age, sometimes reach down to affect younger pigs. Typical of diseases that make their greatest impact on pigs of this age are hog cholera, swine erysipelas, the enteric syndrome (salmonellosis or infectious necrotic enteritis, swine dysentery, or bloody scours), swine influenza, infectious atrophic rhinitis, pasteurellosis, and mycotic infections. The affects of effective populations of external and/or internal parasites come to notice rather markedly in «feeder pigs.»

The presence in a herd of two important infectious diseases are seldom suspected until a particular and significant clinical symptom usually associated with these diseases is displayed. Moreover, this symptom can only be displayed by pregnant females and consists of the expulsion of premature fetuses — an abortion, or the birth at term of weak pigs that die soon after delivery. We refer to brucellosis and leptospirosis. Both, however, could have been detected by suitable serologic tests. Another disease of pregnant sows that has come to our attention on several occasions is one in which the course of a normal pregnancy is suddenly interrupted by death of the fetuses and their subsequent resorption. In about every instance where this has occurred, from 10 to 30 per cent of the pregnant sows have been involved. The cause is not known except that the evidence thus far points away from an infectious agent. Within recent years we have been aware of the occurrence of a subacute to chronic disease of post-parturient sows in which metabolic disturbances similar to what is reported for ketosis in cattle has been found in some of the cases that could be studied. It has been moderately endemic on farms where it has occurred, and many of the affected sows succumbed from the disease.

It is not uncommon to be confronted with a disorder or disease in swine that are four to five or more months of age and where the case history discloses that for the past two or more weeks the patients have shown a poor rate of growth and a poor appetite. The physical examination reveals a normal body temperature, a dry, coarse and shaggy hair coat, a loose and semi-liquid stool, and occasional vomitus. With this history and these signs, a vitamin deficiency disease is suspected with emphasis on one or another of



the B-complex vitamins. A more extended examination of the animal and more critical appraisal of the symptoms may disclose characteristics that would lead to a specific vitamin deficiency. An inspection of the diet by attempting to learn its composition from the standpoint of content, quality, and quantity will, in many cases, help to establish the diagnosis and to identify which vitamin or vitamins are lacking.

A general purview of the herd at the time of the complaint will help to establish if the diet is deficient in the food factor or whether the animal is unable to utilize what is present in the diet. If, for example, 20 per cent or more pigs in a group of 20 or more show the symptoms of a deficiency, then it seems reasonable to assume that the diet did not supply an adequate amount of the vitamin or vitamins involved. Here again, an appraisal of the diet the pigs were receiving for several weeks prior to the time of the complaint often is suggestive of the possibility that a deficiency might exist. A deficiency of this kind would be a deficiency of *intake*.

On the other hand, if only one or a most two pigs in a herd of 20 are affected, it can be interpreted that (a) the requirements of these pigs for the particular food factor is greater than for most pigs, or (b) that the vitamin is not being absorbed and metabolized, even though sufficient is present in the feed. This is a deficiency of *uptake*.

Deficiencies of uptake are much more difficult to recognize but are nonetheless real. It is hard to believe that a pig can suffer from a deficiency in view of the fact that the diet is adequately fortified with these factors.

In conclusion, we have attempted to bring attention to the nature and kinds of disease in swine that we recognize to exist in the United States. It occurred that this could best be done by following a classification of the causes of disease and listing some of the diseases appropriate to the particular category. For the most part only the great divisions of a classification schema were used, and it is hoped that they would afford an insight to the nature of the diseases included in each division, e. g., diseases due to prenatal influences; disease due to disorders of metabolism, growth and nutrition, etc., etc.

We could see no purpose in listing the diseases and making remarks about each one. There are too many. On the other hand, we recognize and acknowledge the importance of such a list and hope that a list of all the diseases in swine in the United States will someday be prepared.

We have a profound belief in the value of data on disease in animals and a faith that records and reports will be gathered, and when processed, will have some of the answers to problems of disease that, until then, we will be obliged to do without.

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MODERATOR. I want to thank the speakers for their highly interesting communications. Now, Dr. Ludvigsen (Denmark) will speak about a very interesting subject: «Maladaptation Syndromes in Pigs».

## MALADAPTATION SYNDROMES IN PIGS

BY

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### INTRODUCTION

The domesticated pig exceeds, in the production of meat, the larger farm animals, because of its quick maturity and high level of reproduction. Originating as a fat type animal, the trend in many countries, especially during the last 20 years has been to the development of rapidly growing, leaner breeds of pigs to comply with the demand for more meat, but less fat, in human consumption. The reasons for changes in eating habits are many, but there



seems to be no doubt that the consumer's preference for tasty palatable, lean meat has largely been due to a general raising of the living standard in the privileged countries. Furthermore current discussions on the influence of fat of animal origin upon the general health of man may also, to some extent, be expected to influence the meat to fat ratio of human diets in favour of meat in the future.

The aim of this paper is to draw attention to some problems in pig breeding, which seem to have followed in the wake of development of meaty pig breeds, special reference being made to some maladaptation syndroms, that seem to be rather important to most branches of swine production ranging from breeding, raising of pigs, health, and disease of stocks to quality of fresh and canned pork, and meat technology.

### THE CONCEPT OF ADAPTATION

Over the last 10 years extensive literature concerning adaptation and stress has been accumulated. Before giving a description of the experimental work which has led to the concept of maladaptation syndroms in pigs, the main principles and pathways of adaptation should briefly be mentioned.

The organism is constantly exposed to changes, not only in its surroundings, but also within its own functions. Under certain conditions the changes to which the organism is exposed can be so violent that they would be fatal, if the organism, through a mobilization of its adaptive capacity, was not able to adapt itself to the changed conditions. The mechanism of adaptation is highly sensitive which e. g. appears from the fact that normal body temperature can be maintained at high and low degrees of environmental temperature; whereas a rise in body temperature of a few degrees feels unpleasant and a rise of 5-6 degrees C generally is fatal. Another example of the adaptive properties of the organism in regard to changes in its own functions is, that muscular activity and exertion might easily be followed by a critical rise in body temperature, if the organism did not possess means to eliminate the heat liberated through its adaptation to the altered physiological conditions.

The adaptive property of the organism has been known for a long time but two events are especially worthy of mention. SELYE'S (1946) formulation of his theories on the General Adaptation Syndrome, and HENCH'S (1949) discovery of the effect of corticotrophine and cortisone on chronic rheumatoid arthritis have been highly inspiring to further investigations within the very important domain of adaptation.

As a general result of the numerous investigations within this field it may be stated that all the organs of the organism in some way or other react and take part in adaptative responses, but the centre of control seems to be in the endocrine system, primarily the pituitary-adrenocortical, the pituitary-thyroid axis, the somatotrophin and the central nervous system, where most of the detectors, which monitor the status quo, are located.

The theory of adaptation has, however, necessitated the introduction of a number of new terms in physiology and pathology.

*Stress*: the term for the reaction of the organism when exposed either to external or internal stimuli e. g. changes in temperature, noxious agents, infections or painful conditions.

*Stressor*: the term for the stimulus which provokes a stress-reaction.

*Adaptive hormones*: a joint term for the hormones which play a major role in the general adaptation syndrome, the most important of which according to our present knowledge are corticotrophine (A. C. T. H.) adrenal cortical steroids, somatotrophin (S. T. H.), the thyroid hormon and adrenaline.

*Maladaptation*: a generic term for clinical symptoms, and syndromes due to disturbances in the mechanism of adaptation.

According to SELYE (1946) the general adaptation syndrome is characterized by three rather well-defined stages. The primary adaptive response is termed the *alarm reaction*, which is the first stage in the general adaptation syndrome. Clinically the alarm reaction among other symptoms is characterized by an increase in the excretion of 17-ketosteroids in the urine. If the organism does not perish in the course of the alarm reaction owing to lesions, it enters the second phase of the general adaptation syndrome, the *stage of resistance*. In this phase there is an increased resistance to the stressor in question and the phase is characterized clinically i. e. by a lower excretion of 17-ketosteroids than normal. If the stressor-effect is longlasting, it may cause a complete breakdown of the internal adaptive regulation, and the stage of resistance is followed by the third phase of the general adaptation syndrome, the *stage of exhaustion*, with acute recurrence of the symptoms of the alarm reaction, the organism finally succumbing to the strain.

## CHANGES IN SKELETAL MUSCLES AS A SYMPTOM OF MALADAPTATION

It has been known for many years that pronounced variations in the appearance of fresh pork may occur. Even adjacent pork muscles frequently exhibit pronounced variation in colour and tissue structure. In some cases all the skeletal muscles of the carcass are discoloured having a pale-grey colour resembling that of white chicken meat. In most cases, however, the discoloration is more pronounced in some muscles than in other muscles. In such cases the definition «two-toned» is a common term. Simultaneously with the pale-grey colour the structure of the musculature is changed macroscopically. The firm, elastic structure has disappeared and the musculature has changed into an unelastic loose structure with moist infiltrations between the muscular bundles. At the same time there is usually a pronounced sour smell, which does not resemble the smell of normal pork of uniform red colour. In Denmark the pale moist muscles are termed MD. This diagnosis will be discussed later in this paper.

Before discussing the pathways of adaptation involved in MD, it should be pointed out, that the pH of MD musculature in comparison with normal musculature is extremely low 30-40 minutes after slaughter due to an accumulation of lactic acid in the musculature (table 1).



TABLE 1

PH AND LACTIC ACID IN SKELETAL MUSCLES 30-45 MINUTES POST MORTEM

|        | m. gracilis |              | m. psoas m. |              | m. long. dorsi |              |
|--------|-------------|--------------|-------------|--------------|----------------|--------------|
|        | pH          | lactic acid  | pH          | lactic acid  | pH             | lactic acid  |
| Normal | 6.5<br>(24) | 520<br>(25)  | 6.1<br>(22) | 752<br>(22)  | 6.4<br>(24)    | 305<br>(24)  |
| MD     | 5.4<br>(12) | 1068<br>(12) | 5.5<br>(11) | 1044<br>(20) | 5.3<br>(13)    | 1201<br>(19) |

Lactic acid given in mg %. Number of observations in brackets.

From the table will be seen that the concentration of lactic acid ranges from 1044 to 1201 mg % in MD and from only 305 to 752 mg % in normal musculature. Concomitantly with the increase in lactic acid the pH in MD has dropped to 5.5-5.3 where as in normal muscles the pH ranges between 6.5 and 6.1.

It is, however, noteworthy that similar changes in skeletal muscles is an unfailing symptom in pigs which have succumbed from fighting during the transportation from the farms to slaughterhouses. Prior to death the affected pigs usually show grave symptoms of dyspnoea, cyanosis, and critical rise in body temperature. Autopsy reveals a series of characteristic changes in the organs. The blood is dark, deoxygenated and accumulated in the splanchnic area, the heart and in the lungs. Pulmonary oedema with frothy blood in the bronchi and trachea is usually very pronounced. The heart is dilated and filled with blood, especially the right auricle and ventricle, and the myocardium is flamelike in colour with petechial bleedings and greatly reduced texture. The skeletal musculature is extremely pale and anaemic, and the temperature immediately after death is within the range of 43.5 to 45 degrees C, the pH 5.3-5.2 and the lactic-acid concentration 1200-1500 mg %. Furthermore marked, oedema and haemorrhages in the meninges and the brain stem are constant symptoms. The common diagnosis of the fatal cases in question is fatal syncope, heat-stroke, hyperthermia or akuter Herztod (German).

As mentioned in Denmark the pale, moist musculature is termed «Muscular Degeneration», abbreviated MD. Actually, the term «Muscular Degeneration» suggests degenerative changes in the musculature resulting in an atrophy of the muscles involved. In severe cases of MD loss of striation, hyaline degeneration, vacuolization and degenerative changes in the nuclei may be present. These alterations indicating degenerative processes, are, however, the more pronounced the higher the temperature in the musculature. Thus most likely the degenerative processes in question are caused by the rise in temperature. Another important evidence, speaking against the disorder being a muscular degeneration, appears solely from the observations that there is an interrelationship between muscular activity and MD, and meatiness and MD.

*MD and exercise.* It is unavoidable that pigs perform muscular activity during transportation from the farms to the slaughterhouses. However, various degrees of MD are most prevalent when pigs are slaughtered immediately after arrival at the slaughterhouse, whereas a mere 3 hours rest at the slaughterhouse before slaughter resulted in a pronounced reduction in the number of carcasses showing MD. Thus it has been demonstrated that the most severe cases were reduced by approx. 70 %. Extension of the resting period to 18 hours was followed by a further decline in the incidence of muscular changes. These observations indicate that the changes in the musculature develop rapidly and are to a large extent reversible, LUDVIGSEN (1954).

The acute development and the pronounced reversibility of the muscular changes in question has led to the assumption that MD is a characteristic organic manifestation of a stress reaction indicating that the organism is in the alarm reaction of the general adaptation syndrome; the organism not being able to adapt itself to muscular activity, LUDVIGSEN (1957).

### THE FREQUENCY OF MD

All pigs from the Danis Progeny Testing Stations are graded visually 24 hours post mortem according to colour and structure of m. longissimus dorsi after cross section of the carcass at the last rib. The following scores for the evaluation of the characteristics are used, CLAUSEN et al. (1956):

| Score    | Specification                                        |
|----------|------------------------------------------------------|
| 0,5      | grey, same colour as boiled meat; very moist surface |
| 1,0      | very pale, pinkish, moist                            |
| 1,5      | pale pink, slightly moist                            |
| 2,0      | slightly paler than desirable, almost dry surface    |
| 2,5— 3,0 | ideal red colour dry firm structure                  |
| 3,5— 4,0 | slightly darker than desirable, dry firm structure   |
| 4,5— 5,0 | very dark.                                           |

From the specification of the scores it will be seen that the scores 0.5 to 2.0 in general characterize various degrees of grey, pale-pinkish and «two-toned» colour and a corresponding more or less moist structure, whereas the scores above 2.0 indicate variations in red colour, but all types with a firm, «dry» structure.

In table 2 results of the grading of the pigs from the progeny testing according to colour and structure in the last 5 years are given, CLAUSEN et al. (1960).

From the table will be seen that on the average, 60 to 62 percent of the carcasses have a normal red colour and firm structure of the meat, whereas the rest of the carcasses show various degrees of alarm reactions in the musculature, the severe cases being indicated between 0.5 and 1.0, the symptoms declining in severity towards 2.0.

The high incidence of MD is to a great extent referable to the fact that the pigs are slaughtered immediately after the transportation from the progeny testing stations to the slaughterhouse.



TABLE II

THE PERCENTUAL DISTRIBUTION OF CARCASSES WITHIN SCORES

| Score | 1954/55<br>% | 1955/56<br>% | 1956/57<br>% | 1957/58<br>% | 1958/59<br>% |
|-------|--------------|--------------|--------------|--------------|--------------|
| 0.5   | 0.6          | 0.3          | 0.3          | 0.3          | 0.2          |
| 1.0   | 3.3          | 2.5          | 2.4          | 1.9          | 2.2          |
| 1.5   | 10.5         | 7.4          | 9.3          | 9.7          | 13.1         |
| 2.0   | 28.4         | 24.1         | 25.4         | 26.4         | 24.3         |
| 2.5   | 39.1         | 44.4         | 40.4         | 40.5         | 37.7         |
| 3.0   | 15.2         | 18.6         | 19.4         | 18.7         | 19.3         |
| 3.5   | 2.5          | 2.4          | 2.5          | 2.6          | 3.0          |
| 4.0   | 0.4          | 0.3          | 0.3          | 0.2          | 0.2          |

Contrary to objective measurements the visual evaluation of meat colour is liable to certain subjective errors, LUDVIGSEN (1958), GATHERUM et al. (1959), OSINSKA and KIELANOWSKI (1960). However as mentioned earlier there is an interrelationship between the pH and the muscular changes; the pH being low in MD. A comparison between colour evaluation and pH has shown, that whereas 46,8 % according to colour scores ranged from 0.5 to 2.0, pH measurements revealed various degrees of MD in 41 % of the material, LUDVIGSEN (1958). This is in agreement with a positive correlation of 0.6 between score for colour and pH found by CLAUSEN et al (1960).

## THE INTERRELATIONSHIP BETWEEN MD AND MEATINESS

An interesting experiment illustrating how far the modern pig has removed from the European Wild Pig according to meatiness and meat colour has been published by CLAUSEN (1953). The results of the crossing experiments are shown in table 3.

Among the results from this experiment it will be seen that from the back-cross generation to F<sub>5</sub> a remarkable decrease in colour score with increased meatiness of the carcass has occurred.

In table 4 some data on the interrelationship between MD and meatiness within the landrace are shown.

The MD pigs in the table refer to an inbred strain (mother x son and father x daughter) for experimental purposes. All the pigs of this particular strain suffered from MD (100 % within colour scores 0.5-2.0) most of them from the severe cases. The two boars x and y are from the same breeding centre. There is a marked difference in the incidence of MD between the two boars ranging from 62.5 % to 25 % on the MD side of the colour scale. From the table it will be seen too that backfat thickness is decreasing while the incidence of various degrees of pale, moist musculature is increasing.

The interrelationship between MD and meatiness in the pigs from the progeny testing stations based on colour score and backfat thickness has been investigated by CLAUSEN et al. (1956). The results are shown in table 5.

**TABLE III**  
THE RESULTS OF CROSSING DANISH LANDRACE WITH EUROPEAN WILD PIG

| Generation, | Wild Pig<br>0/0 | Landrace<br>0/0 | Age at Live<br>Weight, days |       | Daily Weight<br>gain |      | F. U. pr.<br>kg. weight<br>gain | Score<br>for<br>Colour | Grading of Carcass        |      |              |
|-------------|-----------------|-----------------|-----------------------------|-------|----------------------|------|---------------------------------|------------------------|---------------------------|------|--------------|
|             |                 |                 | 20 kg                       |       | 90 kg                |      |                                 |                        | Per cent of Pigs in Grade |      |              |
|             |                 |                 | 20 kg                       | 90 kg | gr.                  | gr.  |                                 |                        | extra thin                | good | Much too fat |
| Back-cross  | 75              | 25              | 142                         | 388   | 286                  | 5.79 | 4.2                             | 0                      | 33                        | 45   | 22           |
| F1          | 50              | 50              | 107                         | 256   | 469                  | 4.44 | 3.8                             | 0                      | 0                         | 14   | 86           |
| F2          | 25              | 75              | 85                          | 217   | 528                  | 3.74 | 2.7                             | 0                      | 38                        | 31   | 31           |
| F3          | 12.5            | 87.5            | 85                          | 198   | 592                  | 3.57 | 2.4                             | 0                      | 50                        | 21   | 29           |
| F4          | 6.3             | 93.8            | 78                          | 193   | 621                  | 3.43 | 2.1                             | 0                      | 80                        | 20   | 0            |
| F5          | 3.1             | 96.9            | 80                          | 181   | 695                  | 3.12 | 1.6                             | 29                     | 71                        | 0    | 0            |
| Landrace    | 0               | 100.0           | 76                          | 180   | 674                  | 3.06 | 1.8                             | 3                      | 83                        | 12   | 2            |

**TABLE IV**  
THE INTERRELATIONSHIP BETWEEN MD AND MEATINESS

|            | No. of pigs | COLOUR SCORE |        |     |     |     |        |     |     |  |  | Backfat cm |
|------------|-------------|--------------|--------|-----|-----|-----|--------|-----|-----|--|--|------------|
|            |             | 0.5          | 1.0    | 1.5 | 2.0 | 2.5 | 3.0    | 3.5 | 4.0 |  |  |            |
| MD         | 18          | 10           | 6      | 1   | 1   | 0   | 0      | 0   | 0   |  |  | 2.80       |
|            |             |              | 100 %  |     |     |     |        |     |     |  |  |            |
| Boar X     | 16          | 0            | 3      | 2   | 5   | 3   | 3      | 0   | 0   |  |  | 3.15       |
|            |             |              | 62.5 % |     |     |     | 37.5 % |     |     |  |  |            |
| Boar Y     | 20          | 0            | 0      | 0   | 5   | 10  | 4      | 1   | 0   |  |  | 3.40       |
|            |             |              | 25 %   |     |     |     | 75 %   |     |     |  |  |            |
| Prog. test | 3471        |              | 34.3 % |     |     |     | 65.7 % |     |     |  |  | 3.20       |



TABLE V

SCORES FOR COLOUR AT DIFFERENT LENGTH OF CARCASS AND BACKFAT THICKNESS

|              |      | Backfat thicknes |       |            |       |           |          |
|--------------|------|------------------|-------|------------|-------|-----------|----------|
|              |      | < 3.0 cm         |       | 3.1-3.4 cm |       | > 3.5 cm  |          |
|              |      | castrates        | gilts | castrates  | gilts | castrates | gilts    |
|              |      |                  |       |            |       |           |          |
| no. of pigs  | 42   | 119              | 305   | 98         | 891   | 997       |          |
| colour score | 2.02 | 2.14             | 2.19  | 2.21       | 2.28  | 2.26      | < 93 cm  |
| no. of pigs  | 142  | 433              | 493   | 525        | 303   | 90        |          |
| colour score | 2.33 | 2.31             | 2.32  | 2.37       | 2.34  | 2.39      | 93-96 cm |
| no. of pigs  | 28   | 155              | 70    | 99         | 39    | 19        |          |
| colour score | 2.38 | 2.34             | 2.29  | 2.39       | 2.38  | 2.50      | > 96 cm  |

Statistical evaluation of the results has shown that the groups especially the male castrates with a length of carcass < 93 cm and backfat thickness < 3.00 cm have a significant lower average colour score than the other groups ( $P \%$ ) < 0.05. This indicates that especially castrates with high meatiness are prone to pale, moist musculature.

Whereas the Danish Landrace is an example of planned selection of meat producing pigs, highly meat producing pigs may develop occasionally. An example of a sporadic evolution of a meat producing pig race is the Piétrain pig in Belgium. Although it is accepted that the Berkshire race has played an important role in the development of the Piétrain race, the basic genetic data remain obscure, CAMERLYNCK and BRANKAER (1958). Since 1957 the Piétrain race has been imported to several countries among others Holland, France, Germany and Denmark. Some preliminary data from the Danish experiments with Piétrain pigs are given in table 6, CLAUSEN (1960):

TABLE VI

MISCELLANEOUS DATA OF PIÉTRAIN PIGS AS COMPARED TO DANISH LANDRACE CONTROLS

|                                        | Piétrain | Landrace |
|----------------------------------------|----------|----------|
| no. of pigs                            | 27       | 40       |
| daily weight gain g (20-90 kg)         | 614      | 692      |
| f. u. pr. kg weight gain*) (20-90 kg)  | 3.30     | 2.95     |
| length of carcass**) cm                | 83.8     | 95.7     |
| backfat thickness cm                   | 3.21     | 2.91     |
| streak thickness cm                    | 3.17     | 3.23     |
| % meat in carcass                      | 61.1     | 57.9     |
| % fat in carcass                       | 28.2     | 29.9     |
| % bones in carcass                     | 10.7     | 12.2     |
| % of pigs within colour scores 0.5-2.0 | 88.9     | 62.5     |

\*) 1. feed unit (f. u.) is equivalent to the nutritive value of 1 kg barley.

\*\*) measured from the first vertebra (atlas) to the anterior end of symphysis pelvis.

Among the data in the table it is noticeable that the carcass of the Piétrain pig is about 12 cm shorter than that of the Landrace. Although the backfat of the Piétrain is 0.3 cm thicker, the lean meat percentage of the carcass is 61.1 i. e. 3.2 % higher than in the Landrace.

From the table will also be seen that there is a remarkable difference between the two races in the colour of the meat. Whereas 62.5 % of the Landrace pigs showed various degrees of pale, moist musculature not less than 88.9 % of the Piétrain pigs showed the same alterations.

JUDGE et al. (1959) studying six different breeds found that «light» colour of the meat was most predominant in the Poland China pigs (60 %) and least predominant in the Large Whites (16.4 %). Firmness described as «soft» was recorded in 62.5 % of the Poland China and 33.6 % of the Large Whites. JANICKI et al. (1954) found that MD predominates in Large White, and was less pronounced in crossbreeds.

## HORMONAL INTERACTION IN THE MD SYNDROME

As mentioned earlier, the most important hormonal systems involved in the adaptive response of the organism are the pituitary-thyroid, the pituitary-adrenal cortex and the growth hormone. In the following the significance of the hormonal systems in question will be considered with special reference to their interaction in MD.

*The role of the thyroid.* The primary suggestion that a lowered activity of the thyroid plays a role in the pathogeny of MD was based on the observation, that MD is more prevalent in summer than in winter. This seemed to be correlated in some way with the activity of the thyroid, which is lower during the warmer seasons than during the colder seasons of the year.

Experimentally the significance of the thyroid in MD has been demonstrated in two different ways.

1. On feeding methyl-thiouracil, 1 g daily 10-14 days prior to slaughter, pathological-anatomical changes in the musculature resembling that of spontaneous MD occurs, LUDVIGSEN (1954). Methyl-thiouracil blocks the synthesis of active hormone in the thyroid gland, and thus causes a decrease in thyroid activity.

2. On stimulating the metabolism of pigs of the aforementioned MD strain (table 4) with iodinated casein 9 to 14 days prior to slaughter a marked decrease in MD occurred, LUDVIGSEN (1954, 1955).

Iodinated casein has the same metabolic effects as the thyroid hormone.

An intriguing observation in these experiments was, that thyroxine obviously had no effect on the muscular changes, although the general metabolic effect was marked. However, the investigations of different preparations revealed that iodinated casein with a high metabolic effect (26.8 % increase in the metabolic rate of mice) had less effect on the muscular changes than iodinated casein with a metabolic effect of only 0.4 % in which case the muscles had a normal red colour.

As mentioned earlier a low pH is one of the characteristics of MD. In



table 7 the results of the determinations of lactic acid and pH in m. psoas major and m. logn dorsi after treatment with the two iodinated casein preparations mentioned and thyroxine are shown.

TABLE VII

LACTIC ACID CONTENT AND PH OF MUSCLES AFTER TREATMENT WITH IODINATED CASEIN AND THYROXINE

|                       | no.<br>of pigs | m. psoas major m.<br>lactic acid mg <sup>0</sup> /0 | pH   | long dorsi<br>lactic acid mg <sup>0</sup> /0 | pH   |
|-----------------------|----------------|-----------------------------------------------------|------|----------------------------------------------|------|
| Controls              | 5              | 980                                                 | 5.42 | 1096                                         | 5.30 |
| iodin. cass. (0.4 %)  | 5              | 908                                                 | 5.84 | 1078                                         | 5.68 |
| iodin. cass. (26.8 %) | 4              | 933                                                 | 5.58 | 1056                                         | 5.48 |
| thyroxine             | 6              | 852                                                 | 5.52 | 967                                          | 5.32 |

From the table it will be seen that the average lactic acid concentration is highest and the pH lowest in the controls. The difference in lactic acid level between the four groups is not significant. It is, however, remarkable that the pH in the muscles of the pigs treated with iodinated casein (0.4 %) is significantly higher, 5.84 and 5.68 in the two muscles respectively than in the control ( $P \% < 0.1$ ). Although the thyroxine treated group has the lowest lactic acid concentration in the experiment the pH is 5.52 and 5.32 in the two muscles and thus within the characteristic pH level of MD. This has given rise to the assumption that although lactic acid plays an important role in fixing the pH level in the musculature, another factor which may be termed the buffer capacity of the muscular proteins, may be of some significance in the adjustment of the pH level after slaughter. The buffer capacity has not been studied in detail, but it seems reasonable to pay some attention to the myoglobin in this respect, as SCAIFE (1955) and BRISKEY et al. (1960) have found that the pH was highest in muscle with a high myoglobin concentration. A possible explanation of the higher pH level in the musculature after treatment with iodinated casein might be that the buffer capacity of the muscular proteins (myoglobin?) has been stimulated as a result of the treatment.

Moreover, in these observations there might be some indication that various fractions of the thyroid hormone may exhibit different metabolic actions.

Thus all evidence seem to indicate that two main factors play an important role in the development of the muscular changes characteristic of MD. The two factors are lactic acid concentration and the buffer capacity. The buffer capacity being low even moderate amounts of lactic acid may provoke low pH levels of 5.5-5.3, whereas in muscles with a high buffer capacity and high amounts of lactic acid the pH may be stabilized at a higher level. The explanation of the moist appearance of MD musculature seems to be the following. The closer the pH is to the iso-electric point of the muscular proteins, which approximates 5.0, the more pronounced is the decrease in the water holding capacity of the proteins. The decrease in the water holding capacity of the proteins is followed by an outflux of water from the muscular cells carrying

water soluble cellular components i. e. electrolytes, low molecular peptides and myoglobin into the extracellular space, thus resulting in a colourless, moist appearance of the muscles. The spontaneous outflux of liquid from the muscular cells seems to begin at a pH around 5.7 and generally reaches its maximum at pH 5.5-5.3, which as mentioned earlier is the characteristic pH level of typical MD.

*The role of the pituitary-adrenal cortex axis.* Several observations indicate that a deficiency of the adrenal cortex is involved in the pathogeny of MD. The synthesis and release of steroids from the adrenal cortex is regulated by the adreno-corticotrophic hormone ACTH of the pituitary gland. In typical cases of MD the content of ACTH in the anterior lobe of the pituitary gland seems to be reduced, table 8.

TABLE VIII

AMOUNT OF ACTH EXTRACTED FROM HYPOPHYSIS OF NORMAL AND MD PIGS

|             | No. of hypophysis | i.U. of ACTH pr. mg. substance |
|-------------|-------------------|--------------------------------|
| normal pigs | 70                | 0.2                            |
| MD pigs     | 70                | 0.1                            |

From the table it will be seen that the amount of ACTH derived from the hypophysis of the MD pigs is only about half of that obtained from the normal pigs.

The role of the pituitary-adrenal cortex axis in MD has been demonstrated experimentally.

The experiments were performed on eight pigs, 4 of the aforementioned MD strain and 4 controls. The pigs were about 6 months of age and weighed 70-85 kg. The pigs were exposed to 10 minutes of moderate muscular exercise; the MD pigs twice, before and after injection of 50 mg hydrocortisone acetate. Blood samples for the determination of lactic acid were taken from an ear vein before starting the exercise and thereafter every 10 minutes for one hour.

In fig. 1 the results of the lactic acid determinations of the controls are shown. From the initial resting value of 15 to 20 mg % the lactic acid rose to a maximum of 160 to 220 mg % after 10 minutes exercise, and the concentration slowly decreased in the following 50 minutes of resting, although it had not yet reached the initial resting value within this period. The pigs revealed no symptoms at all during the exercise.

The MD pigs, however, behaved differently. Four to seven minutes after starting the exercise all 4 pigs showed forced pulmonary ventilation increasing to dyspnoea. At the same time a slight cyanosis developed on the ears and abdomen. With further exercise signs of exhaustion were obvious, and six to ten minutes after the beginning of the experiment the pigs were quite exhausted, and could only move about with great difficulty. During the resting period the dyspnoea gradually disappeared after 15 to 30 minutes, but



the pigs showed marked asthenia for hours, and did not take their normal meal 4 hours later.

In Fig. 2 the lactic curves from the 4 MD pigs are shown. From the initial values ranging from 12 to 25 mg %, 3 of the pigs show only a moderate rise in lactic acid during the 10 minutes of exercise as compared with that of the normal pigs. In one pig the concentration in this period is even lower than the initial resting value. In all 4 pigs low concentrations are still present in the resting period after the exercise.

24 hours later the 4 MD pigs received 50 mg hydrocortisone by injection and one hour after the injection the experiment was repeated. The pigs were now exercised, showing no signs of dyspnoea, cyanosis, or exhaustion and no signs of asthenia were present in the resting period after the exercise. From Fig. 2 it will be seen that after the hydrocortisone injection the lactic acid in the blood from the 4 MD pigs is of the same order as that of the controls. From the initial resting values of 20 to 55 mg % the lactic acid concentration rose from 160 to 220 mg % in 10 minutes and then decreased slowly in the following 50 minutes of resting.

The observation that MD pigs reveal grave symptoms when exercised, whereas all symptoms disappear after treatment with hydrocortisone indicates an adrenal cortical insufficiency in the animals of the MD strain. Concerning the lack of increase of lactic acid in the venous blood in the MD pigs it must be pointed out that microscopically the arterioles and the capillaries in the muscles of pigs suffering from MD are constricted, completely anaemic and usually separated from the muscle fibres by extracellular fluid LUDVIGSEN (1954). The occlusion of the vessels indicates a vasoconstriction in the musculature followed by a decrease in the blood flow. The vasoconstriction and the separation of the circulatory system from the muscle fibres gives a reasonable explanation for the fact that there is no rise in the lactic acid in the bloodstream during exercise. As only moderate amounts or no lactic acid at all enters the blood of MD pigs the lactic acid formed during exercise must be accumulated in the musculature. The fact that the lactic acid produced is accumulated in the muscles of MD affected pigs, has been shown previously in table 2.

The vasoconstriction in the musculature of MD pigs means that the heat liberated from the anaerobic breakdown of creatine phosphate and glycogen to lactic acid during exercise accumulates in the musculature also. The accumulation of heat gives a reasonable explanation for the fact that the temperature in the musculature of MD pigs 20-25 minutes after killing is higher than in normal pigs, and for the extremely high temperatures, 43.5-45.0° C recorded especially in fatal cases.

After the treatment with hydrocortisone the lactic acid output in the blood is within the same range as that of the controls. No symptoms of dyspnoea and cyanosis which are the predominant symptoms of a circulatory insufficiency appeared. This has given rise to the assumption that adrenal cortical hormones as well as all the factors which are involved in the formation and release of hormones in the pituitary-adrenal cortex axis play an important role in vaso-motor reactions. Through their interaction adrenal cortical hormones seem to hold a «key-position» in the adaptability of the circulatory system to the demand for an increased blood supply in the musculature during exercise. Moreover, the increased blood flow in the musculature, followed by a vaso-

constriction in the skin and the splanchnic area obviously does not only serve the purpose of supplying the musculature with adequate oxygen, but also serve the purpose of supplying the musculature with adequate oxygen, but also serves the purpose of removing the excess lactic acid and heat produced from the muscles and thus prevent stress reactions: dyspnoea, cyanosis, hyperthermia and MD.

*Possible role of the growth hormone (S. T. H.).* As mentioned in the introduction the trend in modern pig breeding is, to an ever increasing extent, to produce pigs with as much meat and as little fat as possible. This has been the leading principle e. g. in the development of the Danish Landrace, being based upon the selection of pigs with an increasing conversion rate, thinner backfat, increasing body length and high protein synthesis (increased meatiness).

The development in respect to daily weight gain, feed units pr. kg weight gain, backfat and streak thickness is illustrated in table 9 (data collected from CLAUSEN et al. (1960):

TABLE IX  
DAILY WEIGHT GAIN FOOD CONVERSION FROM 20 TO 90 KG LIVWEIGHT  
THICKNESS OF BACKFAT AND STREAK AND LENGTH OF CARCASS

|      | weight gain<br>daily g | f.u. pr. kg<br>weight gain | backfat<br>cm | streak<br>cm | length-carcass<br>cm |
|------|------------------------|----------------------------|---------------|--------------|----------------------|
| 1925 | 598                    | 3.57                       | 4.18          | 2.98         | 88.5                 |
| 1959 | 685                    | 2.96                       | 2.97          | 3.31         | 95.1                 |

From the table it will be seen that since 1925 the daily weight gain has increased about 90 g and feed units pr. kg weight gain decreased about 0.6. The backfat has decreased from 4.18 to 2.97 cm and the streak has increased from 2.98 to 3.31 cm. Carcass length has increased from 88.5 to 95.1 cm. It should be pointed out that the figures are comparable because the pigs at the progeny testing station were fed the same standard diet consisting of barley and acidified skimmed milk during the period in question. Although no direct measurement of meatiness are available but in scattered data within the period 1925 to 1960 the objective measurements indicate an increased meatiness of the carcass of the Danish Landrace.

Investigations on the aforementioned MD strain of pigs have shown that nitrogen retention is higher in MD than in normal pigs, LUDVIGSEN (1955). The results of the determination of nitrogen retention in eight periods in the interval from 20 to 90 kg liveweight are shown in table 10.

From the table it will be seen that in the MD gilts as well as in the MD male castrates the nitrogen retention is significantly higher than in the corresponding controls.

It is a well established fact that the growth hormone stimulates protein synthesis. Investigations of the effect of growth hormone (STH) has shown that MD may occur after treatment with STH, especially in cases where nitrogen retention is high, LUDVIGSEN (unpubl.).



TABLE X  
NITROGEN RETENTION IN MD PIGS

|                   | MD<br>N. g daily | controls<br>N g daily | Pg <sup>[0/0]</sup> |
|-------------------|------------------|-----------------------|---------------------|
| gilts             | 19.91            | 17.33                 | 0.05                |
| males (castrates) | 17.94            | 15.87                 | 0.05                |

Referring to the interrelation between MD and meatiness there seems to be additional evidence that the development of the meaty pig has resulted in — or more correctly — is a result of a gradual change in homeostasis. The increase in meatiness, higher protein synthesis, might to some extent be referable to the selection of pigs with increased activity of STH. In its general metabolic action STH is antagonistic to the thyrotropic hormone (TSH) and ACTH. Thus, a reliable explanation of the borderline insufficiency of the thyroid and the adrenal cortex in the meaty type of pigs could be, that the increased STH activity has depressed TSH and ACTH activity, which in turn accounts for the higher incidence of MD (stress-reactions) in the meaty pig types.

### MEAT QUALITY

For many years the main criterion for pork quality has been the proportion of lean to fat in the carcass. Pork quality in the approved sense of meat/fat ratio does not in general incorporate the quality of the meaty part of the carcass. In relation to meat quality, the pale, moist or «two-toned» muscles is an important problem, as the condition to a wide extent influences the quality of the final products. The influence of MD on nett yield, colour, consistency and taste of tinned hams and classification of the final product according to commercial standards has been subjected to investigations, LUDVIGSEN (1954, 1955). The nett yield was lower and colour, consistency and taste was inferior as compared to tinned hams produced from normal pork. The classification scores of the MD hams according to commercial standards were so low, that the hams could not be approved for commercial purpose.

From these experiments the conclusion has been drawn, that the physiological and structural pattern of the musculature is a most important factor in commercial quality of final products of pork.

As mentioned earlier the treatment of pigs prior to slaughter to a wide extent influences the frequency of MD. Much attention should be paid to pre-slaughter treatment of the pigs, which is a very important domain of research in respect to MD. A main reason for this is that no technical post-slaughter procedures to improve the detrimental effects of MD hitherto have been found.

## MALADAPTATION AS A CAUSE OF DISEASES

It has been suggested that a joint grouping of a number of apparently widely different diseases in the domestic pig may, with some justification in their basic pathogeny be referable to disturbances in the adaptive mechanism of the organism, LUDVIGSEN (1957). The diseases in question are some common diseases among other atrophic rhinitis, enteritis, post-parturient syndroms with agalactia, metritis and mastitis.

From the basic concept pigs affected with atrophic rhinitis and pigs suffering from chronic diarrhoea (terminal ileitis) were treated with ACTH and corticoids, in order to support the adaptive capacity of the affected pigs.

*Atrophic Rhinitis.* 16 pigs suffering from severe turbinate atrophy, distortion of the snout, sneezing and nasal haemorrhages were treated either with ACTH (Acton prolongatum) 20 i. u. every other day for 14 days, or with 5 ml. of a solution of ACTH, Actocortin and hydrocortisone acetate. Prior to the experiments biopsies were taken from the nasal mucous membrane from several of the animals. The biopsies showed extensive destruction and desquamation of the columnar epithelium. The results of the treatment can be summarized as follows. During the first three or four days no appreciable changes in the clinical condition were observed. From the fifth or sixth day the sneezing attacks were considerably reduced and from the eighth day the pigs were largely non-symptomatic with respect to sneezing and nasal haemorrhages. This condition lasted in the rest of the period of treatment, and in a period of eight to fourteen days after the cessation of the treatment after which a gradual relapse occurred so that the clinical condition about three weeks after the treatment was the same as before the treatment. Biopsies taken immediately after the cessation of the treatment in the symptom-free period, however, showed a marked regeneration of the epithelium of the nasal mucous membrane.

From these results it has been concluded that the effect of ACTH and corticoids on the clinical symptoms, sneezing and bleedings were due to a regeneration of the nasal mucous membrane, LUDVIGSEN (1960).

*Diarrhoea in Pigs.* A most common disease in pigs is diarrhoea and dehydration in the period of weaning. The condition is often fatal. At autopsy pathological changes characteristic of enteritis may either be seen in all sections of the intestinal tract at the same time or more localized in the jejunum or colon. Often the changes are only present in the lower part of jejunum and ileum. It is generally accepted that the common type of enteritis are caused by infections, which of course is supported to a wide extent by the fact that treatment with antibiotics in most cases has a beneficial effect. On the other hand what speaks against enteritis of this type being solely infectious is the fact that in Denmark no specific infective agents have been isolated. In practically all cases investigated, a mixed flora is found, similar to that present in healthy pigs.

In the following some results of an experiment in which pigs with severe diarrhoea and dehydration resistible to antibiotic treatment were treated with



corticoids and ACTH will be mentioned. Having verified the diagnosis of the affected pigs as terminal ileitis by exploratory laparotomy, the pigs were treated with a highly active water soluble corticoid, Actocortin, 50 mg i. m. daily for three days. On the fifth day they received 20 i. u. ACTH. During the treatment the diarrhoea gradually disappeared, appetite increased and hydration followed. In one pig a relapse occurred a fortnight later but after repeating the treatment the pig recovered. After slaughter chronic changes in the terminal ileum were noted, LUDVIGSEN (1958).

It should be mentioned too that terminal or regional ileitis is a well-known clinical entity in human medicine, CROHN et al. (1932) and that the beneficial effect of corticoids in humans suffering from terminal ileitis are reported, among others, by GRAY et al. (1951).

*Possible Mode of Action of Adaptive Hormons.* The beneficial effect of ACTH and corticoids on atrophic rhinitis, and the curative effect on terminal ileitis, has led to a more general concept of the basic pathogeny of these diseases. A joint characteristic of the two diseases, one being localized in the respiratory tract the other in the intestinal tract, is that both diseases are localized in a surface area of the organism and the main symptoms of the affections are referable to lesions of the surface area in question.

The surface areas of the organism, primarily the respiratory tract, the intestinal tract and the skin, are constantly exposed to various stimuli or stressors from the surroundings, among which housing conditions, humidity, bacterial milieu, and feeding are the most important environmental factors. The reaction of the various surface or contact areas theoretically depends on the interaction between the stressor and the adaptive capacity of the organism, and to the extent to which the mechanism of adaptation of the individual in question can be mobilized. If the organism is able to mobilize the adaptive system effectively into the stage of resistance, the contact area exposed will remain intact. If the organism is susceptible to stress-reactions the contact area will react in a rather characteristic way. Obviously the first reaction is a vasodilatation. Often the vascular reactions do not develop further, but if no adaptation has taken place at this stage, prolonged stasis in the circulatory system will be the precursor of exudation and oedemic infiltrations in the submucosa, followed by a critical lack of oxygen in the tissue, which is probably the essential cause of degeneration, eventual destruction and desquamation of the epithelial cover.

The tissue reaction, e. g. in the intestinal mucosa, is followed by disturbances in intestinal function causing diarrhoea. The destruction and dequamation of the epithelium enhances bacterial growth into the tissue. To what extent the secondary infections may aggravate the condition will depend on the pathogeny of the bacterial flora present. The beneficial effect of antibiotics in most cases of acute enteritis is elicited through the eradications of the secondary infection. The eradication of the bacterial flora diminishes the stressor effect due to secondary inflammation of the damaged tissue, and the organism may adapt itself more easily to the original stressor which provoked the primary tissue reaction.

If the organism is not able to adapt itself, prolonged symptomatic reactions will be the dominating expression of the disease, as in the above mentioned cases of atrophic rhinitis and terminal ileitis.

The mechanism by which adaptive hormones elicit their effect can be explained in the following way. The effect of ACTH is due to a stimulation of the adaptive capacity, by an increased production and release of corticoids from the adrenal cortex, whereas the effect of the parentally introduced corticoid is a direct elevation of the concentration of adrenal cortical hormone in blood and tissue. The increased corticoid level in tissue and tissue fluids in some way influences the circulation in the affected nasal mucous membrane and in the intestines so that vasodilatation is released by a venous contraction. The vasoconstriction in the areas in question is followed by an increased circulation of the blood, resorption of the oedema, and thereby an increased oxygen supply. Altogether these reactions seem to be the principal conditions of the regenerative processes of the damaged surface area, and seem to be the actual cause of the epithelial regeneration demonstrated in atrophic rhinitis.

Some evidence points to the fact that there is some correlation between the incidence of MD and the incidence of atrophic rhinitis, LUDVIGSEN (1960). This should not be taken to mean that all pigs suffering from atrophic rhinitis suffer from maladaptation changes in the musculature. The two diseases are, however, each in their own way, a symptom of predisposition to local as well as systemic reactions, that may have some common characteristic of being due to disturbances in the mechanism of adaptation.

## NUTRITIONAL ASPECTS IN MALADAPTATION

The question of maladaptation is not satisfactorily considered without some general comments on the nutritional side of the problem. Since 1930 extensive literature on fatal syncope in pigs has appeared, especially in Germany. The pathological-anatomical manifestations described are the same as those found in fatal cases of the MD syndrome. The losses from fatal syncope are most pronounced in the potato producing areas of Germany, and during the second world war, when the lack of vegetable as well as animal protein was perceptible, the losses increased very heavily, especially in the areas where potatoes were the basic food in production of pigs. The condition has been referred to protein malnutrition and lack of vitamins especially of the B group, HEMMERT-HALZWICK (1950), HUPKA (1953).

There is much, however, which indicates that MD not only is referable to deficiency of protein and vitamins of definite magnitude. Especially carbohydrates seem to be an essential factor. Excess of carbohydrate, both absolute and in relation to protein, vitamins etc. may strain internal metabolic processes affecting the internal regulation. This, amongst other things, may weaken the adaptive system to such an extent that even minor strains can be fatal.

Many irregularities in internal metabolic processes take place without any symptoms. Often diagnosis is first possible when for some or other reason the organism faces e. g. stress conditions. The MD changes in the musculature of many pigs after slaughter may be caused by such irregularities affecting the adaptive mechanism. Thus, theoretically, one could predict that one or other flaw in the feeding ration under given circumstances may cause MD.

Even though this is far from sufficient to elucidate the problems of nutritionally induced stress reactions, it does indicate the importance of an optimal nutrition for the well-being and health of the animals. This naturally



necessitates the need to define the requirements expected from an optimal feed or ration, and an indication of how the requirements can be formulated. Concurrent with the development of nutritional physiology, various approaches to a definition of optimal nutrition have been made. Detailed treatment of these definitions is not possible here, but it should be emphasized that in the definitions of an optimal nutrition are found the concepts of growth, production, reproduction and ability to resist diseases.

The usual way of measuring the value of a certain diet is to measure weight gain and food conversion rate within a certain period. However, total weight increase and food conversion rates must be considered rather unsatisfactory for the evaluation of one or the other diets in respect to optimal composition, since total increase in weight does not indicate, whether the metabolic processes proceed under optimal conditions, or whether the individual tissue structure are optimally developed.

Although there is no claim of scientific proof, the definition of the aspects of optimal nutrition may be formulated as follows:

Optimal nutrition reflects a mixture of nutrients containing sufficient quantities of all the essential components in mutual balance, such that for the species concerned, optimal growth, reproduction and production is maintained, and that the inevitable external and internal influences to which the organism is continuously exposed, proceed with as minimal wear of the internal regulation as possible.

In modern pig breeding it is, in the authors opinion, expedient to distinguish between the genetically and the nutritionally provoked maladaptation. The nutritionally provoked maladaptation needs no consideration if the food and diet has a composition that satisfies the requirements of optimal nutrition, whereas the genetically provoked maladaptation will not be influenced or cured even if the nutrition is optimal.

## CONCLUSION

Attempting to draw a general conclusion it should be emphasized that in modern pig breeding, the important scope of which is to an ever increasing extent to select breeds with genes for maximum meat production, a borderline shift in homeostasis seems to have occurred. In the interaction between many hormonal and enzymatic systems, controlling homeostasis, a depression of the activity of the adaptive hormone systems seems to be of significance in the meaty type of pigs. The symptomatology of the borderline insufficiency of the adaptive systems is an increased susceptibility to:

- a: stress-reactions, MD in the muscles post-slaughter affecting the quality of the meaty part of the carcass,
- b: maladaptation syndroms at the disease level in the respiratory tract
- e. g. Atrophic Rhinitis and in the intestinal tract e. g. Terminal Ileitis.

The beneficial effect of ACTH and adrenal cortical steroids in stress-reactions and maladaptation syndroms in pigs, indicates that adaptive hormones in the future may be of significance in the control of disease levels in the highly meat producing types of pigs.

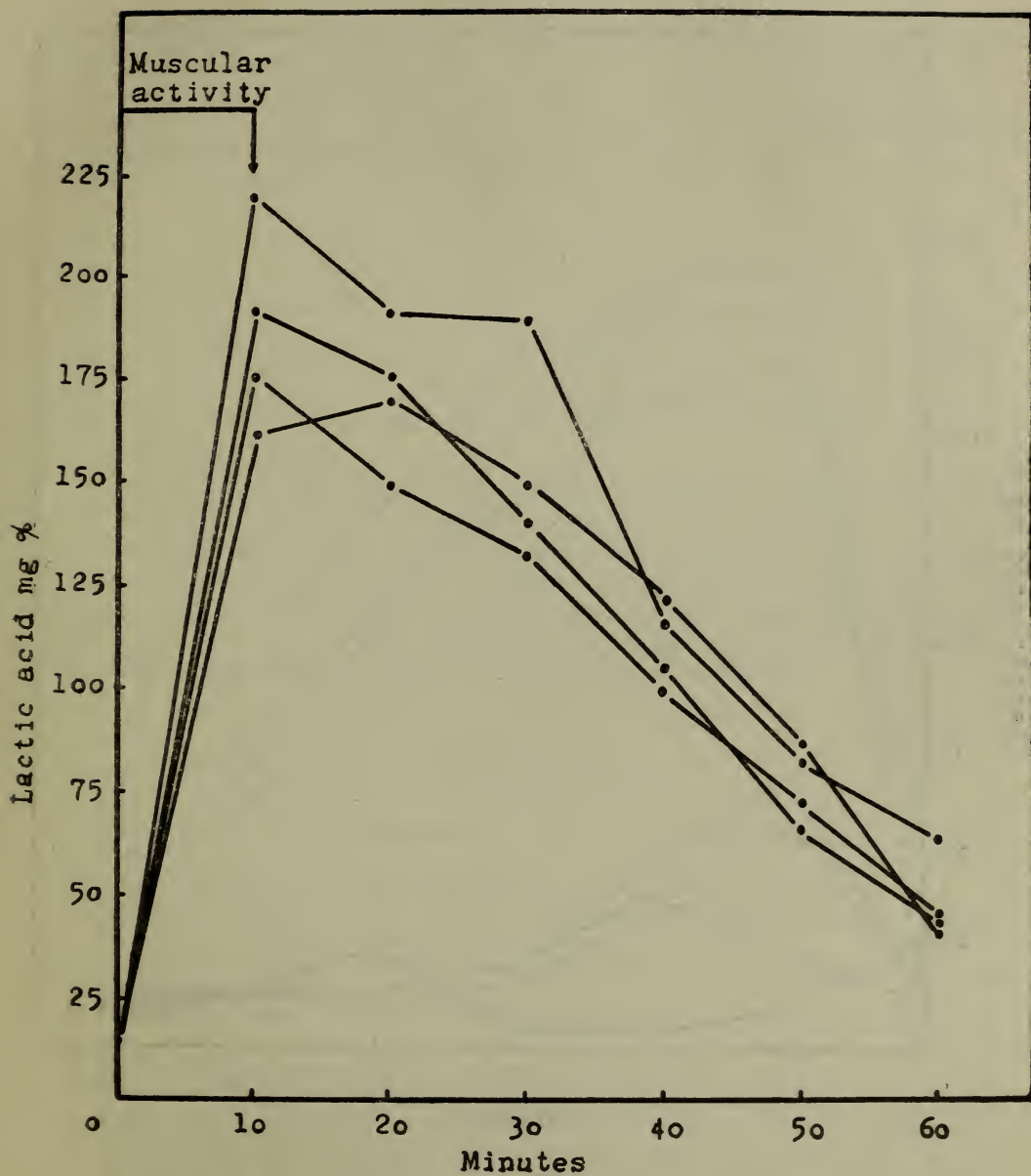


Fig. 1



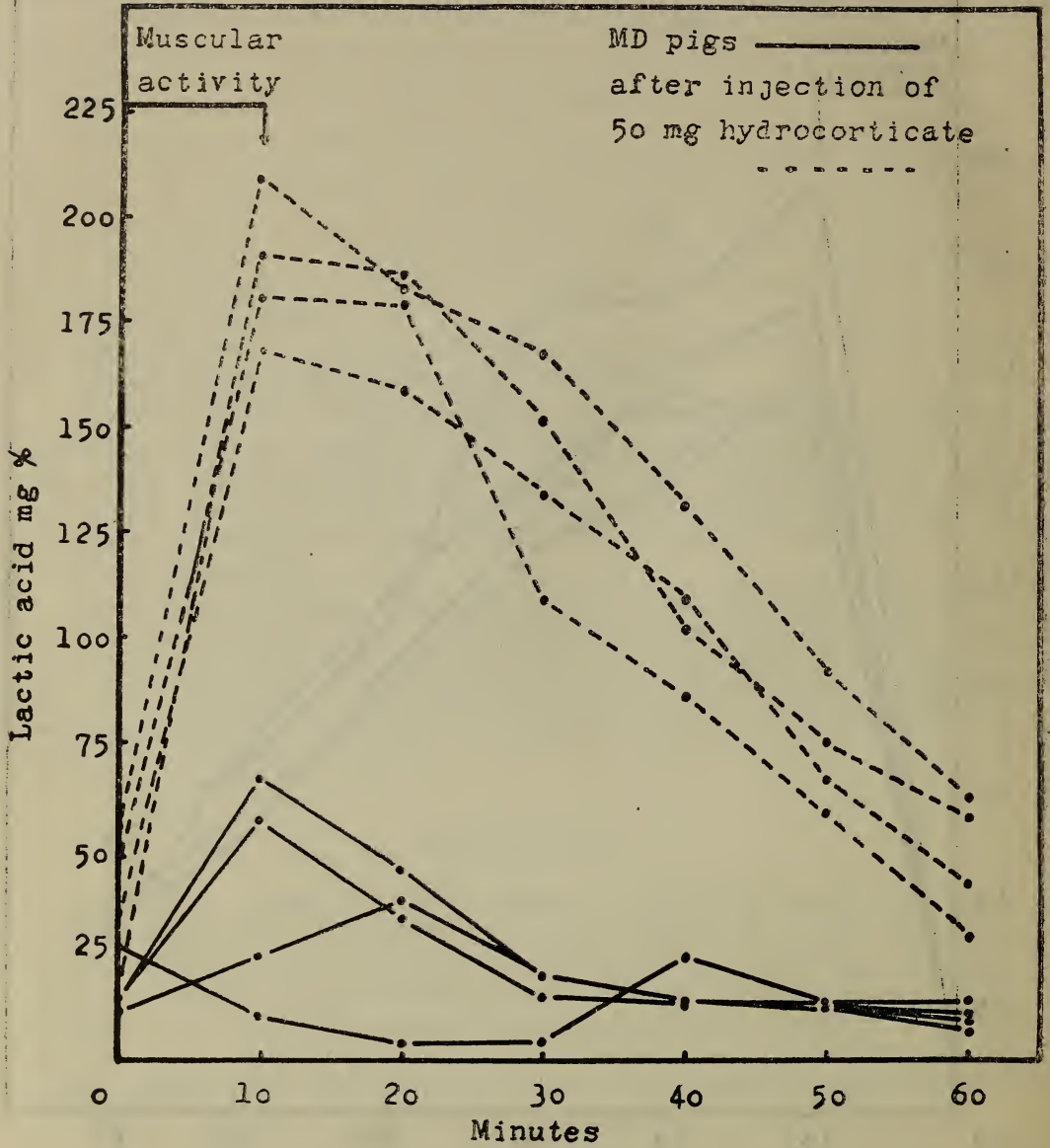


Fig. 2

## SUMMARY

A description of a syndrome termed «muscular degeneration» abbreviated MD in pigs is given. The pale, moist muscles with a low pH 5.5-5.3, characteristic to MD, seems to be caused by an accumulation of lactic acid in skeletal muscles. The interrelation between muscular activity and MD, and the interrelation between meatiness and MD is discussed, on basis of experiments demonstrating the significance of the thyroid gland and the adrenal cortex. A lowered activity of the two endocrine glands in question plays an important role in the pathogeny of the changes in the musculature. The conclusion has been drawn that MD is an organic manifestation of a stress reaction referable to maladaptation. As MD is more prevalent in the meaty types of pigs, it is suggested that the selection of meaty pig types is followed by a decrease in the activity of the thyroid and the adrenal cortex, caused by an increase in the activity of the growth hormone, which in its general metabolic action is antagonistic to the adrenocorticotrophic and the thyrotrophic hormones of the pituitary gland.

The economic importance of the muscular changes is, that pork affected with MD yields final products inferior in quality than normal pork.

From the basic concept that maladaptation is an ethiological factor in some diseases in the respiratory and the intestinal tract, the effect of ACTH and adrenal cortical steroids in pigs suffering from Atrophic Rhinitis and Terminal Ileitis, has been investigated. The beneficial effect and the mode of action of adaptive hormones in the diseases in question is discussed.

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## DISCUSSION

MODERATOR. Thank you very much, Dr. Ludvigsen for your communication, which has a very high practical interest. Now we will leave a few minutes for discussion in case anybody wants to ask any question.

*Dr. Palacios Remondo* (Spain). I would like to ask Dr. Beherens a question. I think Dr. Beherens has not mentioned hepatodistrophy of feeding origin in swine. I would like to know whether there have been any new developments regarding this disease, and whether there has been any successes in this area.

*Dr. Ludvigsen* (Denmark). We do not have this disease in Denmark as an isolated problem.

*Dr. Palacios Remondo* (Spain). Hepatic hepatodistrophy is perfectly defined in human pathology treatises, published in Germany. Several works have been recently published in Spain that deal with this subject. Hepatic hepatodistrophy is a perfectly defined disease of a toxic origin caused by products of animal origin, specially cod-liver oil, which products affect young pigs between 2 and 4 months of age. It starts by increase in body temperature lack of appetite. It is difficult to locate any other symptoms, because the animals die very rapidly.

*Dr. Ludvigsen* (Denmark). I know the disease you are referring to, they have a good amount of cases in Sweden. The Swedes say that vitamin E has a very good effect on this disease.

MODERATOR. Any further question? Well, then I will extend my most sincere thanks to the speakers for their highly interesting contributions. I also want to thank all our audience for the interest they have shown in our sessions.

RESUME OF REPORTS SUBMITTED AT THE VI PANEL OF  
THE 2ND INTERNATIONAL CONFERENCE ON ANIMAL NUTRI-  
TION UNDER THE HEADING «DEVELOPMENTS IN VETERINARY  
SCIENCE» HELD ON THE 22 OCT. 1960

BY

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The Organizing Committee has had the happy notion of including some pathological problems in the Agenda of the 2nd International Conference on Animal Nutrition. Actually, considering the praiseworthy and meritorious efforts performed for the purpose of developing animal breeds of high production and feeding such breeds adequate rations, it would be most regrettable if such efforts were to become fruitless because of the outbreak of some type of epidemic in the breeds.

The Reports submitted by Dr. Pomeroy and Dr. Cuckler dealt with poultry breeding and the problem of coccidiostats.

The extraordinary density of the poultry population has caused the outbreak of new diseases, among which those of the respiratory tract represent a very serious problem for the breeding of broilers. Vaccination has become a must in order to assure the profitability of this type of activity, and the same applies to the use of diets with a high antibiotic content (200 grams per ton).

With respect to laying hens, infectious bronchitis brings about a considerable decrease in egg production.

In the case of coccidiosis, a very harmful disease to poultry husbandry, many coccidiostats have already been tested for the purpose of reducing the



economic incidence of this disease, with the result that, at present, a wide line of highly effective products are available to the producer.

By stopping the feeding of rations supplemented with such products three days prior to slaughter a total elimination of said products from the organs and muscles intended for human consumption is assured.

As regards ruminants, Dr. Link has reviewed recent diseases in beef and dairy cattle. Several of these diseases are of a viral nature, but others show a vitamin or mineral deficiency, or are due to the presence of a toxic substance in the food.

With respect to dairy cattle, mammitis remains a very important problem. Dr. Sacchi has carried out a very thorough study on this subject, pointing out the most adequate means of fighting such a disease with satisfactory results.

There have been three Reports on the subject «pathology of pigs,» by Drs. Behrens, Kernkamp and Ludvigsen.

Pig diseases may be of a congenital nature; in most cases, however, they are due to bacterial agents or to a virus of some kind. There are also diseases of toxic character, circulatory or cardiac diseases due to nutritive deficiencies and, unfortunately, an impressively large series of affections, the etiology of which remains unknown so far.

The peculiar conditions under which pig breeding is carried out may result in disorders due to maladaptation of the animals.

The problems of animal pathology deserve indeed adequate attention from research workers for the purpose of developing effective means of fighting those diseases which adversely affect animal productivity. All participants have contributed with their valuable experience towards the development of this important field of veterinary science and therefore deserve our most sincere gratitude.

## FINAL SESSION

*Dr. Cuenca.* Ladies and Gentlemen: This is the final session of the II International Animal Nutrition Conference. Mr. Kohn, please.

*Dr. Kohn.* Mr. Chairman, Ladies and Gentlemen: It is with great pleasure that I say I have been assigned by the participants to the present Conference to extend our most sincere thanks to Msrss. Goeppinger and Roach for their kind hospitality and for their efforts in organizing this Conference, and making a success of it. I also would like to express my congratulations to the organizers for their selection of all the Panels, one of which I have had the pleasure to supervise. My task has been an agreeable and easy one. It is not my intention to bore you in an attempt to resume everything that has been said here. I will only say I am very satisfied with the general approach, with the general orientation given to our Panel; interrelation between the different activities related to animal nutrition and an effective team work are the factors that will permit us reach our objectives. I will try to mention some examples of such team work by summarizing very briefly from the communications presented under our Panel. Dr. Ascarelli reviewed the nature of the relations of carotene and vitamin A and the role they play in cattle feeding. We must also mention Dr. Simpson dissertation, who reviewed the more recent applications and developments in the use of fat-soluble vitamins. He also disserted on the more recent commercial developments and about the scientific application of the knowledge regarding preservation of unstable elements of vitamin A. I was particularly impressed by everything Dr. Simpson said regarding the existing interrelationships between little known relations, and the increasing levels of nitrate in the pastures, because of hig fertilization levels. Also, the question of carotene conversion into vitamin A is a very important point, Dr. Stockstad acted in the double capacity of speaker on the subjects «Water Soluble Vitamins» and «Role of Selenium and Vitamin E in Nutrition», and gave us a very interesting dissertation on both subjects. He talked about the need for a careful selenium control because selenium, while being an essential element in animal nutrition, may also kill the animal. In his second paper, Dr. Stockstad made a general resumé of animal needs regarding different factors of Vitamin B. This lecture was very interesting and was supplemented by slides. Dr. Runnels has demonstrated how our search for new factors can result in a more



accurate chemical isolation of some of these factors, how the systematical study of interrelations between known components of a given type may help us to improve animal feeds.

Dr. James McGinness told us about research work performed regarding the nutritional value of enzyme supplements to animal feeds, specially for young animals, the digestive capacity of which is not fully developed. In this case we see how some unexpected factor appearing during reasearch gives the whole clue to the problems studied. Dr. McGinness explained how they found that, as the same time that they discovered that enzyme supplements improved the nutritional value of barley, they also observed that the simple wetting of ground barley was even more effective than enzyme supplementation for improving nutritional value, and how they found later that microbial fermentation was responsible for most of the improvement in nutritional value or barley. This process is now known as water-treatment. He also explained the role played by geographic and climatic conditions in the production of enzymes of the type involved in water treatment.

Finally, it seems to me that we should emphasize in all research work mentioned under this Panel the importance of cooperation and team work. I only would like to add that we are very grateful to the organizers of the Conference for the selection of papers presented here. It is to them that we owe the opportunity of listening to so many interesting dissertations. Thank you very much. (Applauses.)

*Dr. Cuenca (Spain).* Now we come to the second part of the Final Session of the II International Animal Nutrition Conference, under the Chairmanship of Don Miguel Echegaray, Agronomic Engineer, and President of the Spanish National Institute for Agronomical Research.

*Mr. Echegaray.* Ladies and Gentlemen: Now we will proceed to the second part of the final session of the II International Animal Nutrition Conference. Dr. Simpson, please.

*Dr. Simpson (U. S. A.).* This is my first visit to Spain. When I leave, I will do it with the wish to come back again in order to renew the friendships I have made here and to get to improve my knowledge about this beautiful country. It has been a real pleasure for me to be with you during this week. I also want to extend my most sincere thanks to Mr. Echegaray for all his efforts and his warm kindness towards all of us. My congratulations to Dr. Cuenca, who has been a very efficient Chairman to our Conference. Our most sincere gratitude to all the staff of the Soybean Council and to the local people which have done such a wonderful job of preparing all the necessary details for making our Conference a real success. Last but not least, our most warm appreciation to all the people who have participated in the present Conference. All of them have contributed with their personal cooperation and their willingness to accept the necessary changes in the programs. I think these sessions have provided a very interesting exchange of ideas for everybody concerned. I do not want to bother you with a lengthy speech. Therefore, I will only add that I hope I will have the chance to meet you again here, in your own countries, or in the United States. Thank you very much to everybody. (Applauses.)

*Mr. Echegaray.* Thank you very much Dr. Simpson. Now, Dr. Goeppinger will proceed. Dr. Goeppinger, please.

*Dr. Goepfinger.* Mr. Chairman, scientists of animal nutrition from all the world. The three Panels included in the first part of our sessions this week have provided a good deal of information which were quite new for me. Not being a professional in these matters, I know all this information has a great interest for all of you, because in this way you have been able to keep up to date on new developments of international scope. Both the Soybean Council of America, under the Presidency of Mr. Roach and the U. S. Grain Council, which I have the honour to preside, are very grateful to all of you who through your cooperation and personal contributions, have stolen time from your many duties and responsibilities to bring new ideas to the free world, to bring the hope of a better, healthier living to all the people of the world.

These meetings contribute to improve international friendship and understanding. In this modern world of us, we are more than neighbours; in 7 or 8 hours we may come from all corners of the world and meet here in Madrid.

I also want to extend our thanks to all the personnel of the Soybean Council in Madrid, to the staff and officials of the «Instituto de Investigaciones» which have offered their premises for our Conference, to the Press, interpreters and stenographers, to all the people who have contributed to the success of these meetings. Also, our most sincere appreciation to the Foreign Agricultural Service of the U. S. Department of Agriculture for the cooperation given us in organizing this Conference. Thank you very much. (Applauses.)

*Mr. Echegaray.* Thank you very much, Dr. Goepfinger. Now, Dr. Roach will proceed. Dr. Roach, please.

*Dr. Roach.* Mr. Chairman, Ladies and Gentlemen: It would be a repetition on my part to state our thanks to all the people who have contributed to our Conference. The II International Animal Nutrition Conference has been a real success. We feel that all participants from 15 different countries who have met here have become something more than mere friends, we feel that somehow we have become a great family meeting together to discuss our common problems. I only want to add to these words that yesterday I called Mr. Stafer, Director of the Nutrition Section of the Soybean Council, who has contributed with his efforts to the organization of our Conference, and he was very impressed by the amount of people who had participated in this Conference, specially from Germany. When told about the names of the participants, he asked me to bring a message to you, that he was very sorry he had been unable to come here and meet the many friends he has among the participants.

I also want to say that it might be possible to organize further conferences of this type. We all are at your disposal, the Soybean Council as well as the U. S. Grain Council. I entreaty you not to write to us with words of praise, keep those for the participants, who have truly deserved them. However, if you feel there is something that should be criticised, please let us know so that we can do better in the future. Deep in my heart I say farewell to all of you, and may we meet so many old friends and make new ones. Thank you very much. (Applauses.)

*Mr. Echegaray.* Now we arrive to the end of this meeting. First of all, I would like to express my sincere gratitude for the honor conferred on me to preside these last moments of our II International Animal Nutrition Conference. I do not deserve it and I am not prepared for it, however I



can say that I speak for everybody when I say that all contributions presented here have been of the highest interest and that there has been a wonderful spirit of cooperation on the part of everybody concerned.

I want to say again that these meetings have a basic importance in the world we live in. Before one of these Conferences, the technicians and scientists from all the world know about each other, read the works of their fellow colleagues and so on; however, when they all participate in one of these Conferences, they become a team working together for the same purpose. Even if you have to part now, the impact of your personalities upon your fellow participants will remain, and therefore you will continue as a closely united team, working together for the welfare of mankind.

My last words to thank everybody on behalf of our Ministry for all the kind words addressed to us, and to pay our compliments to Messrs. Roach and Goeppinger and to Dr. Cuenca for his most excellent work at the Technical Secretariat. Our thanks also to Mr. Salas who, as an untiring soldier for the Soybean Council in Madrid has done such a wonderful job.

Ladies and Gentlemen: The II International Animal Nutrition is hereby concluded. Thank you very much. (Applauses.)

END THE SESSION

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